SOLICITATION, OFFER AND AWARD

1. THIS CONTRACT IS A RATED ORDER UNDER DPAS (15 CFR 700)	RATING		PAGE OF PAGES	1 67

2. CONTRACT NUMBER	3. SOLICITATION NUMBER	4. TYPE OF SOLICITATION	5. DATE ISSUED	6. REQUISITION/PURCHASE NUMBER
	NNK12427490R	☐ SEALED BID (IFB) ☒ NEGOTIATED (RFP)	04/18/2012	

7. ISSUED BY CODE KSC	8. ADDRESS OFFER TO (If other than Item 7)
NASA/John F. Kennedy Space Center Office of Procurement MAIL CODE OP-MS/Chelsea Poling KENNEDY SPACE CENTER FL 32899	See Section L

NOTE: In sealed bid solicitations "offer" and "offeror" mean "bid" and "bidder".

SOLICITATION

9. Sealed offers in original and REFER TO SECTION L copies for furnishing the supplies or services in the Schedule will be received at the place specified in Item 8, or if hand carried, in the depository located in ______ until 1400 ET *(Hour)* local time 05/18/2012 *(Date)*

CAUTION: LATE Submissions, Modifications, and Withdrawals: See Section L, Provision No. 52.214-7 or 52.215-1. All offers are subject to all terms and conditions contained in this solicitation.

10. FOR INFORMATION CALL:	A. NAME	B. TELEPHONE (NO COLLECT CALLS) AREA CODE	NUMBER	EXT.	C. E-MAIL ADDRESS
	Chelsea M. Poling	321	867-6651		chelsea.poling@nasa.gov

11. TABLE OF CONTENTS

OFFER *(Must be fully completed by offeror)*

NOTE: Item 12 does not apply if the solicitation includes the provisions at 52.214-16, Minimum Bid Acceptance Period.

12. In compliance with the above, the undersigned agrees, if this offer is accepted within ______ calendar days (60 calendar days unless a different period is inserted by the offeror) from the date for receipt of offers specified above, to furnish any or all items upon which prices are offered at the price set opposite each item, delivered at the designated point(s), within the time specified in the schedule.

13. DISCOUNT FOR PROMPT PAYMENT *(See Section I, Clause No. 52.232.8)*	10 CALENDAR DAYS (%)	20 CALENDAR DAYS (%)	30 CALENDAR DAYS (%)	CALENDAR DAYS (%)

14. ACKNOWLEDGEMENT OF AMENDMENTS *(The offeror acknowledges receipt of amendments to the SOLICITATION for offerors and related documents numbered and dated):*	AMENDMENT NO.	DATE	AMENDMENT NO.	DATE

15A. NAME AND ADDRESS OF OFFEROR	CODE	FACILITY	16. NAME AND TITLE OF PERSON AUTHORIZED TO SIGN OFFER *(Type or print)*

15B. TELEPHONE NUMBER AREA CODE	NUMBER	EXT.	15C. CHECK IF REMITTANCE ADDRESS ☐ IS DIFFERENT FROM ABOVE - ENTER SUCH ADDRESS IN SCHEDULE.	17. SIGNATURE	18. OFFER DATE

AWARD *(To be completed by government)*

19. ACCEPTED AS TO ITEMS NUMBERED	20. AMOUNT	21. ACCOUNTING AND APPROPRIATION

22. AUTHORITY FOR USING OTHER THAN FULL AND OPEN COMPETITION:	23. SUBMIT INVOICES TO ADDRESS SHOWN IN *(4 copies unless otherwise specified)*	ITEM
☐ 10 U.S.C. 2304 (c) ( ) ☐ 41 U.S.C. 253 (c) ( )		

24. ADMINISTERED BY *(If other than Item 7)*	CODE	25. PAYMENT WILL BE MADE BY	CODE

26. NAME OF CONTRACTING OFFICER *(Type or print)*	27. UNITED STATES OF AMERICA	28. AWARD DATE
Chelsea M. Poling	*(Signature of Contracting Officer)*	

IMPORTANT - Award will be made on this Form, or on Standard Form 26, or by other authorized official written notice.

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INDEX OF CLAUSES FOR NNK12427240R

SECTION M-- EVALUATION FACTORS FOR AWARD

SECTION B OF NNK12427240R
SUPPLIES OR SERVICES AND PRICES/COSTS

B.1 DELIVERABLE REQUIREMENTS AND DELIVERY SCHEDULE

The Contractor shall perform and/or deliver items in accordance with Section J.1, Attachment C, Deliverable Items List and Schedule.

B.2 FIRM FIXED PRICE (1852.216-78) (DEC 1988) (For Offeror Fill-In)

The total firm fixed price of this contract is: To be determined at time of contract award

CLIN	Description	Quantity	Unit	Unit Price	Total Price
001	**BASE CONTRACT** Vacuum Development Unit (VDU) Gas Chromatograph – Mass Spectrometer (GC-MS)	1	JOB	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**
002	**BASE CONTRACT** Repair Parts in accordance with SOW 2.14	1	LOT	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**
003	**OPTION 1*** Vacuum Development Unit (VDU) Gas Chromatograph – Mass Spectrometer (GC-MS)	1	EA	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**
004	**OPTION 2*** Vacuum Development Unit (VDU) Gas Chromatograph – Mass Spectrometer (GC-MS)	1	EA	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**

*Upon completion of the Critical Design Review (CDR), the successful offeror will be notified if option(s) will be exercised. It is anticipated option quantities if exercised, would be fabricated concurrently with base contract VDU GC-MS. Reference Section I.1 FAR Clause 52.217-7-- OPTION FOR INCREASED QUANTITY -- SEPARATELY PRICED LINE ITEM (MAR 1989).

B.3 MILESTONE PAYMENT SCHEDULE (For Offeror Fill-In)

(a) Subject to other limitations and conditions specified in this contract, milestone payments shall be made to the Contractor upon delivery and acceptance of the milestone events described under paragraph (b).

(b) The payment schedule amount shall be calculated by the application of the contract percentage established per milestone event to the total fixed price amount indicated under contract clause B.2, entitled "Firm-Fixed Price".

BASE CONTRACT: CLIN 001 and CLIN 002

Milestone Event	Quantity	Contract Value Percentage	Unit Price	Total Amount	Completion Determination
Monthly Status Reports (Design Phase)	10	5%	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**	Received as described in Attachment A and C
Preliminary Design Review (PDR)	1	6%	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**	Received as described in Attachment A and C
Continuation Review (CR)	1	3%	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**	Received as described in Attachment A and C
Critical Design Review (CDR)	1	6%	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**	Received as described in Attachment A and C
Monthly Status Reports (Build Phase)	14	5%	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**	Received as described in Attachment A and C
Validation & Verification Testing Procedure	1	15%	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**	Received as described in Attachment A, B and C
Vacuum Development Unit and Repair Parts	1	40%	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**	Received as described in Attachment A, B and C
Final Presentation	1	20%	**$ TO BE PROPOSED**	**$ TO BE PROPOSED**	Received as described in Attachment A and C
CLIN 001 and 002 Total		100%		**$ TO BE PROPOSED**	

(c) The Contractor may submit requests for payment not more frequently than monthly, in a form and manner acceptable to the Contracting Officer. Unless otherwise authorized by the Contracting Officer, all milestone payments in any period for which payment is being requested shall be included in a single request, appropriately itemized and totaled.

(d) The Contractor shall not be entitled to payment of a request for milestones payment prior to successful accomplishment and acceptance by the Government of the milestone event. The Contracting Officer shall determine whether the milestone event or performance criterion for which payment is requested has been successfully accomplished and accepted by the Government in accordance with the terms of the contract. The Contracting Officer may, at any time, require the Contractor to substantiate the successful performance of any event or performance criterion which has been or is represented as being payable.

(End of Text)

SECTION C OF NNK12427240R
DESCRIPTION/SPECIFICATIONS/WORK STATEMENT

C.1 SCOPE OF WORK

The Contractor shall provide the personnel, materials and facilities, except as otherwise provided in the contract, necessary to provide the items described below and as described under Section J.1, Attachment A, Statement of Work for the Vacuum Development Unit (VDU) Gas Chromatograph-Mass Spectrometer (GC-MS) for the Lunar Advanced Volatile Analysis (LAVA) Subsystem dated February 29, 2012; Section J.1, Attachment B, Technical Specification for the Vacuum Development Unit Gas Chromatograph-Mass Spectrometer dated February 29, 2012; and Section J.1, Attachment C, VDU GC-MS Deliverable Items List and Schedule (DILS).

(End of clause)

C.2 DATA REQUIREMENT LIST

A. The Contractor shall furnish all data identified and described in Section J.1, Attachment C, VDU GC-MS Deliverable Items List and Schedule (DILS, and in supplemental DRLs to be subsequently furnished to the Contractor for additional data which the Government is authorized to request in accordance with the terms of this contract. Such data shall be prepared in accordance with the Data Requirement Description – KSC Form 16-246 (hereinafter called DRD) attached to the DRL and referenced in the DRL for each line item of data specified in the DRL.

B. The Government reserves the right to reasonably defer the date of delivery of any or all line items of data specified in the DRL. Such right may be exercised at no increase in the contract amount. The Government also reserves the right to terminate the requirement for any or all line items of data specified in the DRL. In the event the Government exercises this latter right, the contract amount shall be subject to equitable adjustment in accordance with the clause hereof entitled “Changes – Fixed-Price”.

C. To the extent that data required to be furnished by other provisions of this contract area also identified and described in the DRL, or supplemental DRLs, and in the DRDs referenced in such DRL(s), compliance with the DRL shall be accepted as compliance with such other provisions. In the event of conflict between the identity and description of data called for by specific provision of this contract and the DRL or DRDs, the DRL and DRDs shall control the data to be furnished.

D. Nothing contained in this Data Requirements List provision shall relieve the Contractor from furnishing data called for by, or under the authority of, other provisions of this contract which are not identified and described in the DRL attached to this contract. Whenever such data are identified, either by the Contractor or the Government, they will be listed on a DRL and described on DRDs.

(End of clause)

SECTION D OF NNK12427240R
PACKAGING AND MARKING

D.1 PACKAGING, HANDLING, AND TRANSPORTATION (1852.211-70) (SEP 2005)

D.2 CLAUSES INCORPORATED BY REFERENCE -- SECTION D

Clause(s) at the beginning of this Section are incorporated by reference, with the same force and effect as if they were given in full text. Clauses incorporated by reference which require a fill-in by the Government include the text of the affected paragraph(s) only. This does not limit the clause to the affected paragraph(s). The Contractor is responsible for understanding and complying with the entire clause. The full text of the clause is available at the addresses contained in clause 52.252-2, Clauses Incorporated by Reference, of this contract.

SECTION E OF NNG10EK04R
INSPECTION AND ACCEPTANCE

E.1 RESPONSIBILITY FOR SUPPLIES (52.246-16) (APR 1984)

E.2 INSPECTION OF SUPPLIES—FIXED PRICE (52.246-2) (AUG 1996)

E.3 INSPECTION OF RESEARCH AND DEVELOPMENT- FIXED PRICE (52.246-7) (AUG 1996)

E.4 MATERIAL INSPECTION AND RECEIVING REPORT (1852.246-72) (AUG 2003)

(a) At the time of each delivery to the Government under this contract, the Contractor shall furnish a Material Inspection and Receiving Report (DD Form 250 series) prepared in two copies, an original and a copy.
(b) The Contractor shall prepare the DD Form 250 in accordance with NASA FAR Supplement 1846.6. The Contractor shall enclose the copies of the DD Form 250 in the package or seal them in a waterproof envelope, which shall be securely attached to the exterior of the package in the most protected location.
(c) When more than one package is involved in a shipment, the Contractor shall list on the DD Form 250, as additional information, the quantity of packages and the package numbers. The Contractor shall forward the DD Form 250 with the lowest numbered package of the shipment and print the words "CONTAINS DD FORM 250" on the package.

(End of clause)

E.5 GOVERNMENT CONTRACT QUALITY ASSURANCE FUNCTIONS (1852.246-71) (OCT 1988)

In accordance with the Inspection clause of this contract, the Government intends to perform the following functions at the locations indicated:

QUALITY ASSURANCE ITEM	QA FUNCTION	LOCATION
Testing	Monitoring and Witnessing by Government QA Representatives	Contractor and Subcontractor Facilities
Electronic Assemblies	Inspection of electronic assemblies prior to their installation	Contractor and Subcontractor Facilities
Mechanical Assemblies	Inspection of mechanical assemblies prior to assembly into next higher level of assembly	Contractor and Subcontractor Facilities
Manufacturing Process	Monitoring of various manufacturing processes for compliance	Contractor and Subcontractor Facilities
Procedural and Requirements Compliance	Surveys, audits, and monitoring of compliance to procedures and requirements	Contractor and Subcontractor Facilities

(End of clause)

E.6 HIGHER-LEVEL CONTRACT QUALITY REQUIREMENTS (52.246-11) (FEB 1999)

The Contractor shall comply with the higher-level quality standard selected below.

Title	Reference	Date
Quality Assurance Plan	SAE AS9100 NPD 8730.5	To Be Proposed (TBP)

(End of text)

E.7 CLAUSES INCORPORATED BY REFERENCE -- SECTION E

Clause(s) at the beginning of this Section are incorporated by reference, with the same force and effect as if they were given in full text. Clauses incorporated by reference which require a fill-in by the Government include the text of the affected paragraph(s) only. This does not limit the clause to the affected paragraph(s). The Contractor is responsible for understanding and complying with the entire clause. The full text of the clause is available at the addresses contained in clause 52.252-2, Clauses Incorporated by Reference, of this contract.

SECTION F OF NNG10EK04R
DELIVERIES OR PERFORMANCE

F.1 STOP-WORK ORDER (52.242-15) (AUG 1989)

F.2 F.O.B. DESTINATION (52.247-34) (NOV 1991)

F.3 DELIVERABLE ITEMS AND SCHEDULE

See Section J.1, Attachment C.

F.4 SHIPPING INSTRUCTIONS

Items shipped under this Contract shall be sent to:

NASA Transportation Officer
Attention: Contract Number*
Marked for: Janine Captain, NE-L5 (321-867-6970)
Warehouse Building M6-744
Kennedy Space Center, FL 32899

*Reference NASA Contract Number: **TBD**

(End of clause)

F.5 CLAUSES INCORPORATED BY REFERENCE -- SECTION F

Clause(s) at the beginning of this Section are incorporated by reference, with the same force and effect as if they were given in full text. Clauses incorporated by reference which require a fill-in by the Government include the text of the affected paragraph(s) only. This does not limit the clause to the affected paragraph(s). The Contractor is responsible for understanding and complying with the entire clause. The full text of the clause is available at the addresses contained in clause 52.252-2, Clauses Incorporated by Reference, of this contract.

SECTION G OF NNK12427240R
CONTRACT ADMINISTRATION DATA

G.1 NEW TECHNOLOGY (1852.227-70) (MAY 2002)

G.2 DESIGNATION OF NEW TECHNOLOGY REPRESENTATIVE AND PATENT REPRESENTATIVE (1852.227-72) (JULY 1997)

(a) For purposes of administration of the clause of this contract entitled "New Technology" or "Patent Rights – Ownership by the Contractor", whichever is included, the following named representatives are hereby designated by the Contracting Officer to administer such clause:

Title	Office Code	Address (including zip code
New Technology	CC	Kennedy Space Center Representative KSC, FL 32899
Patent	CC	Kennedy Space Center Representative KSC, FL 32899

(b) Reports of reportable items, and disclosure of subject inventions, interim reports, final reports, utilization reports, and other reports required by the clause, as well as any correspondence with respect to such matters, should be directed to the New Technology Representative unless transmitted in response to correspondence or request from the Patent Representative. Inquiries or requests regarding disposition of rights, election of rights, or related matters should be directed to the Patent Representative. This clause shall be included in any subcontract hereunder requiring a "New Technology" clause or "Patent Rights—Ownership by the Contractor" clause, unless otherwise authorized or directed by the Contracting Officer. The respective responsibilities and authorities of the above-named representatives are set forth in 1827.305-370 of the NASA FAR Supplement.

(End of clause)

G.3 TECHNICAL DIRECTION (1852.242-70) (SEP 1993)

(a) Performance of the work under this contract is subject to the written technical direction of the Contracting Officer Technical Representative (COTR), who shall be specifically appointed by the Contracting Officer in writing in accordance with NASA FAR Supplement 1842.270. "Technical direction" means a directive to the Contractor that approves approaches, solutions, designs, or refinements; fills in details or otherwise completes the general description of work or documentation items; shifts emphasis among work areas or tasks; or furnishes similar instruction to the Contractor. Technical direction includes requiring studies and pursuit of certain lines of inquiry regarding matters within the general tasks and requirements in Section C of this contract.

(b) The COTR does not have the authority to, and shall not, issue any instruction purporting to be technical direction that -

(1) Constitutes an assignment of additional work outside the statement of work;

(2) Constitutes a change as defined in the changes clause;

(3) Constitutes a basis for any increase or decrease in the total estimated contract cost, the fixed fee (if any), or the time required for contract performance;

(4) Changes any of the expressed terms, conditions, or specifications of the contract; or

(5) Interferes with the contractor's rights to perform the terms and conditions of the contract.

(c) All technical direction shall be issued in writing by the COTR.

(d) The Contractor shall proceed promptly with the performance of technical direction duly issued by the COTR in the manner prescribed by this clause and within the COTR's authority. If, in the Contractor's opinion, any instruction or direction by the COTR falls within any of the categories defined in paragraph (b) of this clause, the Contractor shall not proceed but shall notify the Contracting Officer in writing within 5 working days after receiving it and shall request the Contracting Officer to take action as described in this clause. Upon receiving this notification, the Contracting Officer shall either issue an appropriate contract modification within a reasonable time or advise the Contractor in writing within 30 days that the instruction or direction is -

(1) Rescinded in its entirety; or

(2) Within the requirements of the contract and does not constitute a change under the changes clause of the contract, and that the Contractor should proceed promptly with its performance.

(e) A failure of the contractor and contracting officer to agree that the instruction or direction is both within the requirements of the contract and does not constitute a change under the changes clause, or a failure to agree upon the contract action to be taken with respect to the instruction or direction, shall be subject to the Disputes clause of this contract.

(f) Any action(s) taken by the contractor in response to any direction given by any person other than the Contracting Officer or the COTR shall be at the Contractor's risk

G.4 INVOICES – SUMBISSION OF

Invoices shall be prepared in accordance with the Prompt Payment clause of this contract and submitted to the NASA Shared Services Center (NSSC). For purposes of the Prompt Payment Act, the below office is considered to be the "Designated Billing Office" and the "Designated Payment Office."

NASA Shared Services Center
Financial Management Division (FMD)
Accounts Payable

Building 1111, C Road
Stennis Space Center, MS 39529-6000

Phone: 1-877-677-2123
FAX: 1-866-209-5415
E-mail: NSSC-AccountsPayable@nasa.gov

Invoices shall be submitted in accordance with Section B.3 MILESTONE PAYMENT SCHEDULE.

G.5 CLAUSES INCORPORATED BY REFERENCE -- SECTION G

Clause(s) at the beginning of this Section are incorporated by reference, with the same force and effect as if they were given in full text. Clauses incorporated by reference which require a fill-in by the Government include the text of the affected paragraph(s) only. This does not limit the clause to the affected paragraph(s). The Contractor is responsible for understanding and complying with the entire clause. The full text of the clause is available at the addresses contained in clause 52.252-2, Clauses Incorporated by Reference, of this contract

SECTION H OF NNK12427240R
SPECIAL CONTRACT REQUIREMENTS

H.1 RESTRICTIONS ON PRINTING AND DUPLICATING (1852.208-81) (NOV 2004)

H.2 SAFETY AND HEALTH (1852.223-70) (APR 2002)

H.3 MAJOR BREACH OF SAFETY OR SECURITY (1852.223-75) (FEB 2002)

H.4 FINAL SCIENTIFIC AND TECHNICAL REPORTS (1852.235-73) (DEC 2006)

H.5 GEOGRAPHIC PARTICIPATION IN THE AEROSPACE PROGRAM (1852.244-70) (APR 1985)

H.6 EXPORT LICENSES (1852.225-70) (FEB 2000)

(a) The Contractor shall comply with all U.S. export control laws and regulations, including the International Traffic in Arms Regulations (ITAR), 22 CFR Parts 120 through 130, and the Export Administration Regulations (EAR), 15 CFR Parts 730 through 799, in the performance of this contract. In the absence of available license exemptions/exceptions, the Contractor shall be responsible for obtaining the appropriate licenses or other approvals, if required, for exports of hardware, technical data, and software, or for the provision of technical assistance.
(b) The Contractor shall be responsible for obtaining export licenses, if required, before utilizing foreign persons in the performance of this contract, including instances where the work is to be performed on-site at any Government installation, where the foreign person will have access to export-controlled technical data or software.
(c) The Contractor shall be responsible for all regulatory record keeping requirements associated with the use of licenses and license exemptions/exceptions.
(d) The Contractor shall be responsible for ensuring that the provisions of this clause apply to its subcontractors.

EXPORT CONTROL CLASSIFICATION

3A233 Mass spectrometers, other than those described in 0B002.g, capable of measuring ions of 230 atomic mass units or greater and having a resolution of better than 2 parts in 230, and ion sources therefore.
<u>License Requirements</u>
Reason for Control: NP, AT
Control(s) Country Chart
NP applies to entire entry NP Column 1
AT applies to entire entry AT Column 1
<u>License Exceptions</u>
LVS: N/A
GBS: N/A
CIV: N/A
<u>List of Items Controlled</u>
Unit: Number
Related Controls: (1) See ECCNs 3E001 (“development” and “production”) and 3E201 (“use”) for technology for items controlled under this entry.

(2) Mass spectrometers specially designed or prepared for analyzing on-line samples of UF_6 gas streams are subject to the export licensing authority of the Nuclear Regulatory Commission (see 10 CFR part 110).

(End of clause)

H.7 LIMITATION OF FUNDS (FIXED-PRICE CONTRACT) (1852.232-77) (MAR 1989)

(a) Of the total price of the total price of the basic effort, the sum of **$ TO BE DETERMINED** is presently available for payment and allotted to this contract. It is anticipated that from time to time additional funds will be allocated to the contract in accordance with the following schedule, until the total price of said item is allotted:

SCHEDULE FOR ALLOTMENT OF FUNDS

Date	Amounts
	TO BE DETERMINED

(b) The Contractor agrees to perform or have performed work on the items specified in paragraph (a) above up to the point at which, if this contract is terminated pursuant to the Termination for Convenience of the Government clause of this contract, the total amount payable by the Government (including amounts payable for subcontracts and settlement costs) pursuant to paragraphs (f) and (g) if that clause would, in the exercise of reasonable judgment by the Contractor, approximate the total amount at the time allotted to the contract. The Contractor is not obligated to continue performance of the work beyond that point. The Government is not obligated in any event to pay or reimburse the Contractor more than the amount from time to time allotted to the contract, anything to the contrary in the Termination for Convenience of the Government clause notwithstanding.

(c) (1) It is contemplated that funds presently allotted to this contract will cover the work to be performed until To Be Determined.

(2) If funds allotted are considered by the Contractor to be inadequate to cover the work to be performed until that date, or an agreed date substituted for it, the Contractor shall notify the Contracting Officer in writing when within the next 60 days the work will reach a point at which, if the contract is terminated pursuant to the Termination for Convenience of the Government clause of this contract, the total amount payable by the Government (including amounts payable for subcontracts and settlement costs) pursuant to paragraphs (f) and (g) of that clause will approximate 75 percent of the total amount then allotted to the contract.

(3) (i) The notice shall state the estimated date when the point referred to in subparagraph (2) above will be reached and the estimated amount of additional funds required to continue performance to the date specified in subparagraph (1) above, or an agreed date substituted for it.

(ii) The Contractor shall, 60 days in advance of the date specified in subparagraph (1) above, or an agreed date substituted for it, advise the Contracting Officer in writing as to the estimated amount of additional funds required for the timely performance of the contract for a further period as may be specified in the contract or otherwise agreed to by the parties.

(4) If, after the notification referred to in subdivision (3)(ii) above, additional funds are not allotted by the date specified in subparagraph (1) above, or an agreed date substituted for it, the Contracting Officer shall, upon the Contractor's written request, terminate this contract on that date or on the date set forth in the request, whichever is later, pursuant to the Termination for Convenience of the Government clause.

(d) When additional funds are allotted from time to time for continued performance of the work under this contract, the parties shall agree on the applicable period of contract performance to be covered by these funds. The provisions of paragraphs (b) and (c) above shall apply to these additional allotted funds and substituted date pertaining to them, and the contract shall be modified accordingly.

(e) If, solely by reason of the Government's failure to allot additional funds in amounts sufficient for the timely performance of this contract, the Contractor incurs additional costs or is delayed in the performance of the work under this contract, and if additional funds are allotted, an equitable adjustment shall be made in the price or prices (including appropriate target, billing, and ceiling prices where applicable) of the items to be delivered, or in the time of delivery or both.

(f) The Government may at any time before termination, and, with the consent of the Contractor, after notice of termination, allot additional funds for this contract.

(g) The provisions of this clause with respect to termination shall in no way be deemed to limit the rights of the Government under the Default clause of this contract. The provisions of this Limitation of Funds clause are limited to the work on and allotment of funds for the items set forth in paragraph (a) above. This clause shall become inoperative upon the allotment of funds for the total price of said work except for rights and obligations then existing under this clause.

(h) Nothing in this clause shall affect the right of the Government to terminate this contract pursuant to the Termination for Convenience of the Government clause of this contract.

(End of clause)

H.8 KEY PERSONNEL AND FACILITIES (1852.235-71) (MAR 1989)

(a) The personnel and/or facilities listed below (or specified in the contract Schedule) are considered essential to the work being performed under this contract. Before removing, replacing, or diverting any of the listed or specified personnel or facilities, the Contractor shall (1) notify the Contracting Officer reasonably in advance and (2) submit justification (including proposed substitutions) in sufficient detail to permit evaluation of the impact on this contract.

(b) The Contractor shall make no diversion without the Contracting Officer's written consent; provided, that the Contracting Officer may ratify in writing the proposed change, and that ratification shall constitute the Contracting Officer's consent required by this clause.

(c) The list of personnel and/or facilities (shown below or as specified in the contract Schedule) may, with the consent of the contracting parties, be amended from time to time during the course of the contract to add or delete personnel and/or facilities.

[*List here the personnel and/or facilities considered essential, unless they are specified in the contract Schedule – TBP*.]

H.9 ADDITIONAL REPORTS OF WORK--RESEARCH AND DEVELOPMENT (1852.235-74) (FEB 2003)

In addition to the final report required under this contract, the Contractor shall submit the following report(s) to the Contracting Officer:

(a) Monthly progress reports. The Contractor shall submit separate monthly reports of all work accomplished during each month of contract performance. Reports shall be in narrative form, brief, and informal. They shall include a quantitative description of progress, an indication of any current problems that may impede performance, proposed corrective action, and a discussion of the work to be performed during the next monthly reporting period.

(b) RESERVED

(c) Submission dates. Monthly reports shall be submitted by the 14th day of the month following the month being reported. If the contract is awarded beyond the middle of a month, the first monthly report shall cover the period from award until the end of the following month. No monthly report need be submitted for the final month of contract effort since that period will be covered in the final report. The final report shall be submitted within 30 days after the completion of the effort under the contract.

(End of clause)

H.10 GOVERNMENT INDUSTRY DATA EXCHANGE PROGRAM (GIDEP)

Consistent with NPR 8735.1 (Procedures for Exchanging Parts, Materials, and Safety Problem Data Utilizing Government-Industry Data Exchange Program and NASA Advisories), the Contractor shall review all GIDEP ALERTS, GIDEP SAFE-ALERTS, GIDEP Problem Advisories, GIDEP Agency Action Notices, and NASA Advisories to determine if they affect the Contractor's products/and or services provided to the Government. For GIDEP ALERTS, GIDEP SAFE-ALERTS, GIDEP Problem Advisories, GIDEP Agency Action Notices, and NASA Advisories that affect the contractor's products and services provided to the Government, the contractor shall take action to eliminate or mitigate any negative effect.
The contractor shall generate applicable failure experience data report(s) (GIDEP ALERT, GIDEP SAFE-ALERT, GIDEP Problem Advisory) in accordance with the requirements of GIDEP S0300-BT-PRO-010 and S0300-BU-GYD-010 whenever failed or nonconforming items, available to other buyers, are discovered during the course of the Contract.

The contractor shall insert this section in any subcontract for supplies hereunder exceeding $500,000.00 or supplying safety critical item(s) as identified by the Contract. When so inserted, the words, "Contractor" should be changed to "Subcontractor," and "Government" should be changed to "Customer."

(End of clause)

H.11 CLAUSES INCORPORATED BY REFERENCE -- SECTION H

Clause(s) at the beginning of this Section are incorporated by reference, with the same force and effect as if they were given in full text. Clauses incorporated by reference which require a fill-in by the Government include the text of the affected paragraph(s) only. This does not limit the clause to the affected paragraph(s). The Contractor is responsible for understanding and complying with the entire clause. The full text of the clause is available at the addresses contained in clause 52.252-2, Clauses Incorporated by Reference, of this contract

SECTION I OF NNK12427240R
CONTRACT CLAUSES

I.1 CLAUSES INCORPORATED BY REFERENCE (52.252-2) (FEB 1998)

This contract incorporates one or more clauses by reference, with the same force and effect as if they were given in full text. Upon request, the Contracting Officer will make their full text available. Also, the full text of a clause may be accessed electronically at this/these address(es):

Federal Acquisition Regulation (FAR) clauses:

http://www.arnet.gov/far/

NASA FAR Supplement (NFS) clauses:

http://www.hq.nasa.gov/office/procurement/regs/nfstoc.htm

A. FAR CLAUSES INCORPORATED BY REFERENCE

(52.202-1)	DEFINITIONS (JAN 2012)
(52.203-3)	GRATUITIES (APR 1984)
(52.203-5)	COVENANT AGAINST CONTINGENT FEES (APR 1984)
(52.203-6)	RESTRICTIONS ON SUBCONTRACTOR SALES TO THE GOVERNMENT (SEP 2006)
(52.203-7)	ANTI-KICKBACK PROCEDURES (OCT 2010)
(52.203-8)	CANCELLATION, RESCISSION, AND RECOVERY OF FUNDS FOR ILLEGAL OR IMPROPER ACTIVITY (JAN 1997)
(52.203-10)	PRICE OR FEE ADJUSTMENT FOR ILLEGAL OR IMPROPER ACTIVITY (JAN 1997)
(52.203-12)	LIMITATION ON PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (OCT 2010)
(52.204-4)	PRINTED OR COPIED DOUBLE-SIDED ON POSTCONSUMBER FIBER CONTENTPAPER (MAY 2011)
(52.204-7)	CENTRAL CONTRACTOR REGISTRATION (FEB 2012)
(52.204-10)	REPORTING EXECUTIVE COMPENSATION AND FIRST-TIER SUBCONTRACT AWARDS. (FEB 2012)
(52.209-6)	PROTECTING THE GOVERNMENT'S INTEREST WHEN SUBCONTRACTING WITH CONTRACTORS DEBARRED, SUSPENDED, OR PROPOSED FOR DEBARMENT (DEC 2010)
(52.209-9)	UPDATES OF PUBLICLY AVAILABLE INFORMATION REGARDING RESPONSIBILITY MATTERS (FEB 2012)
(52.211-5)	MATERIAL REQUIREMENTS (AUG 2000)
(52.215-2)	AUDIT AND RECORDS--NEGOTIATION (OCT 2010)
(52.215-8)	ORDER OF PRECEDENCE--UNIFORM CONTRACT FORMAT (OCT 1997)
(52.215-11)	PRICE REDUCTION FOR DEFECTIVE COST OR PRICING DATA--MODIFICATION (AUG 2011)

(52.215-13)	SUBCONTRACTOR COST OR PRICING DATA--MODIFICATIONS (OCT 2010)
(52.215-14)	INTEGRITY OF UNIT PRICES (OCT 2010)
(52.215-15)	PENSION ADJUSTMENTS AND ASSET REVERSIONS (OCT 2010)
(52.215-18)	REVERSION OR ADJUSTMENT OF PLANS FOR POSTRETIREMENT BENEFITS (PRB) OTHER THAN PENSIONS (JULY 2005)
(52.215-21)	REQUIREMENTS FOR COST OR PRICING DATA OR INFORMATION OTHER THAN COST OR PRICING DATA—MODIFICATIONS (OCT 2010)
(52.217-7)	OPTION FOR INCREASED QUANTITY- SEPERATLEY PRICED LINE ITEM (MAR 1989)
(52.219-8)	UTILIZATION OF SMALL BUSINESS CONCERNS (JAN 2011)
(52.219-9)	SMALL BUSINESS SUBCONTRACTING PLAN (JAN 2011)—ALTERNATE II (OCT 2001)
(52.219-16)	LIQUIDATED DAMAGES – SUBCONTRACTING PLAN (JAN 1999)
(52.219-25)	SMALL DISADVANTAGED BUSINESS PARTICIPATION PROGRAM--DISADVANTAGED STATUS AND REPORTING (DEC 2010)
(52.219-28)	POST-AWARD SMALL BUSINESS PROGRAM REPRESENTATION (APR 2009)
(52.222-1)	NOTICE TO THE GOVERNMENT OF LABOR DISPUTES (FEB 1997)
(52.222-3)	CONVICT LABOR (JUN 2003)
(52.222-19)	CHILD LABOR--COOPERATION WITH AUTHORITIES AND REMEDIES (MAR 2012)
(52.222-20)	WALSH-HEALEY PUBLIC CONTRACTS ACT (OCT 2010)
(52.222-21)	PROHIBITION OF SEGREGATED FACILITIES (FEB 1999)
(52.222-26)	EQUAL OPPORTUNITY (MAR 2007)
(52.222-35)	EQUAL OPPORTUNITY FOR VETERANS (SEP 2010)
(52.222-36)	AFFIRMATIVE ACTION FOR WORKERS WITH DISABILITIES (OCT 2010)
(52.222-37)	EMPLOYMENT REPORTS ON VETERANS (SEP 2010)
(52.222-50)	COMBATING TRAFFICKING IN PERSONS (FEB 2009)
(52.222-54)	EMPLOYMENT ELIGIBILITY VERIFICATION (JAN 2009)
(52.223-6)	DRUG FREE WORK PLACE (MAY 2001)
(52.223-18)	ENCOURAGING CONTRACTOR POLICIES TO BAN TEXT MESSAGING WHILE DRIVING (AUG 2011)
(52.225-1)	BUY AMERICAN ACT--SUPPLIES (FEB 2009)
(52.225-13)	RESTRICTIONS ON CERTAIN FOREIGN PURCHASES (JUN 2008)
(52.225-25)	PROHIBITION ON ENGAGING IN SANCTIONED ACTIVITES RELATING TO IRAN-CERTIFICATION (NOV 2011)
(52.227-1)	AUTHORIZATION AND CONSENT (DEC 2007) ALT I (APR 1984)
(52.227-2)	NOTICE AND ASSISTANCE REGARDING PATENT AND COPY-RIGHT INFRINGEMENT (DEC 2007)
(52.227-3)	PATENT INDEMNITY (APR 1984) ALT I (APR 1984) ALT II (APR 1984)
(52.227-11)	PATENT RIGHTS-OWNERSHIP BY THE CONTRACTOR (DEC 2007) ALT I (JUN 1989) ALT II (DEC 2007)
(52.227-14)	RIGHTS IN DATA-GENERAL (52.227-14)(DEC 2007)— ALTERNATE I (DEC 2007), (ALTERNATE II (DEC 2007) AND ALTERNATE III (DEC 2007)
(52.227-16)	ADDITIONAL DATA REQUIREMENTS (JUN 1987)

(52.229-3)	FEDERAL, STATE, AND LOCAL TAXES (APR 2003)
(52.230-2)	COST ACCOUNTING STANDARDS (OCT 2010)
(52.230-3)	DISCLOSURE AND CONSISTENCY OF COST ACCOUNTING PRACTICES (OCT 2008)
(52.232-1)	PAYMENTS (APR 1984)
(52.232-8)	DISCOUNTS FOR PROMPT PAYMENT (FEB 2002)
(52.232-11)	EXTRAS (APR 1984)
(52.232-17)	INTEREST (OCT 2010)
(52.232-18)	AVAILABILITY OF FUNDS (APR 1984)
(52.232-23)	ASSIGNMENT OF CLAIMS (JAN 1986)
(52.232-25)	PROMPT PAYMENT (OCT 2008)
(52.232-33)	PAYMENT BY ELECTRONIC FUNDS TRANSFER—CENTRAL CONTRACTOR REGISTRATION (OCT 2003)
(52.233-1)	DISPUTES (JULY 2002)
(52.233-3)	PROTEST AFTER AWARD (AUG 1996)
(52.233-4)	APPLICABLE LAW FOR BREACH OF CONTRACT CLAIM (OCT 2004)
(52.237-3)	CONTINUITY OF SERVICES (JAN 1991)
(52.239-1)	PRIVACY OR SECURITY SAFEGUARDS (AUG 1996)
(52.242-13)	BANKRUPTCY (JUL 1995)
(52.243-1)	CHANGES--FIXED PRICE (AUG 1987) – ALT V (APR 1984)
(52.243-7)	NOTIFICATION OF CHANGES (APR 1984)
(52.244-2)	SUBCONTRACTS (OCT 2010) {Paragraph (d) is "None" and paragraph (j) is “None"}
(52.244-6)	SUBCONTRACTS FOR COMMERCIAL ITEMS (DEC 2010)
(52.246-24)	LIMITATION OF LIABILITY--HIGH VALUE ITEMS (FEB 1997)--ALTERNATE I (APR 1984)
(52.248-1)	VALUE ENGINEERING (OCT 2010)
(52.249-2)	TERMINATION FOR CONVENIENCE OF THE GOVERNMENT (FIXED PRICE) (APR 2012)
(52.249-9)	DEFAULT (FIXED-PRICE RESEARCH AND DEVELOPMENT) (APR 1984)
(52.253-1)	COMPUTER GENERATED FORMS (JAN 1991)

B. NASA FAR SUPPLEMENT-CLAUSES INCORPORATED BY REFERENCE

(1852.219-74)	USE OF RURAL AREA SMALL BUSINESSES (SEP 1990)
(1852.219-75)	SMALL BUSINESS SUBCONTRACTING REPORTING (MAY 1999)
(1852.219-77)	NASA MENTOR PROTÉGÉ PROGRAM (MAY 2009)
(1852.225-71)	RESTRICTIONS ON FUNDING ACTIVITY WITH CHINA (FEB 2012)
(1852.227-11)	PATENT RIGHTS--RETENTION BY THE CONTRACTOR (SHORT FORM)
(1852.227-14)	RIGHTS IN DATA—GENERAL
(1852.235-70)	CENTER FOR AEROSPACE INFORMATION (DEC 2006)
(1852.243-71)	SHARED SAVINGS (MAR 1997)

(End of By Reference Section)

I.2 UPDATES OF INFORMATION REGARDING RESPONSIBILITY MATTERS (52.209-8) (APR 2010)

(a) The Contractor shall update the information in the Federal Awardee Performance and Integrity Information System (FAPIIS) on a semi-annual basis, throughout the life of the contract, by entering the required information in the Central Contractor Registration database at http://www.ccr.gov (see 52.204-7).

(b)(1) The Contractor will receive notification when the Government posts new information to the Contractor's record.

(2) The Contractor will have an opportunity to post comments regarding information that has been posted by the Government. The comments will be retained as long as the associated information is retained, *i.e.*, for a total period of 6 years. Contractor comments will remain a part of the record unless the Contractor revises them.

(3) With the exception of the Contractor, only Government personnel and authorized users performing business on behalf of the Government will be able to view the Contractor's record in the system. Public requests for system information will be handled under Freedom of Information Act procedures, including, where appropriate, procedures promulgated under E.O. 12600.

(End of clause)

I.3 MANAGEMENT OF NASA-OWNED/CONTRACTOR-HELD RECORDS (KSC 52.245-90) (SEP 2009)

(a) NASA-owned/Contractor-held records shall be maintained by the Contractor in accordance with the instructions set forth in the latest editions of NPD 1440.6, NASA Records Management Program, NPR 1441.1, NASA Records Retention Schedules, and KNPD 1440.1, KSC Records Management and Vital Records Programs and, KDP-KSC-P-1881 Records Management. As directed by the Contracting Officer, the Contractor shall obtain prior approval from the Contracting Officer to destroy or remove records subject to this clause.

(b) NASA-owned/Contractor-held records shall consist of documentation of Contractor activities and functions necessary for the performance of this contract, including, but not limited to, documentation of those day-to-day operating procedures that are essential to carrying out the statement of work and those actions, organizational structure, policies, decisions, operations, and activities necessary to perform or continue the work performed under the contract. NASA-owned/Contractor-held records shall not include those Contractor records that relate exclusively to the Contractor's internal business or are of a general nature not specifically related to the performance of work under the contract. The Contractor's general policies, procedures, etc., that apply to the general conduct of its business do not fall under the purview of this clause. When in doubt, the Contractor shall seek the Contracting Officer's determination as to which records are subject to this clause.

(c) The Contractor shall ensure that NASA-owned/Contractor-held records are segregated from company-owned records and from non-record materials. This clause operates independently from and is not intended to affect, or be effected by, the Contractor records provisions contained in FAR Subpart 4.7 and the clauses referenced therein.

(d) The Contractor, through the Contracting Officer, shall coordinate with the KSC Records Manager, on matters requiring advice, such as marking and segregating such records, or technical assistance in all areas of management pertaining to such records.

(e) When the contractor generates NASA-owned/Contractor-held records, the contractor shall prepare and submit KSC Form 16-473V2, KSC Annual Summary of Record Holdings, to the KSC Records Manager on an annual basis.

(End of clause)

I.4 AUTHORIZED DEVIATIONS IN CLAUSES (52.252-6) APR 1984)

(a) The use in this solicitation or contract of any Federal Acquisition Regulation (48 CFR Chapter 1) clause with an authorized deviation is indicated by the addition of (DEVIATION) after the date of the clause.

(b) The use in this solicitation or contract of any NASA FAR Supplement Regulation (48 CFR Chapter 18) clause with an authorized deviation is indicated by the addition of "(DEVIATION)" after the name of the regulation. (48 CFR 18) clause with an authorized deviation is indicated by the addition of (DEVIATION) after the name of the regulation.

(End of clause)

I.5 OMBUDSMAN (1852.215-84) (OCT 2003)

(a) An ombudsman has been appointed to hear and facilitate the resolution of concerns from offerors, potential offerors, and contractors during the preaward and postaward phases of this acquisition. When requested, the ombudsman will maintain strict confidentiality as to the source of the concern. The existence of the ombudsman is not to diminish the authority of the contracting officer, the Source Evaluation Board, or the selection official. Further, the ombudsman does not participate in the evaluation of proposals, the source selection process, or the adjudication of formal contract disputes. Therefore, before consulting with an ombudsman, interested parties must first address their concerns, issues, disagreements, and/or recommendations to the contracting officer for resolution.

(b) If resolution cannot be made by the contracting officer, interested parties may contact the installation ombudsman,

Kelvin M. Manning
NASA Kennedy Space Center
Mailcode: AA-B
Room 4111, Bldg: M6-0399
Kennedy Space Center, FL 32899
P: 321.867.7246
F: 321.867.7787
kelvin.m.manning@nasa.gov

Concerns, issues, disagreements, and recommendations which cannot be resolved at the installation may be referred to the NASA ombudsman, the Director of the Contract Management Division, at 202-358-0445, facsimile 202-358-3083, e-mail james.a.balinskas@nasa.gov. Please do not contact the ombudsman to request copies of the solicitation, verify offer due date, or clarify technical requirements. Such inquiries shall be directed to the Contracting Officer or as specified elsewhere in this document.

(End of clause)

I.6 NASA 8 PERCENT GOAL (1852.219-76) (JUL 1997)

(a) Definitions.

“Historically Black Colleges or University”, as used in this clause means an institution determined by the Secretary of Education to meet the requirements of 34 CFR Section 608.2. The term also includes any nonprofit research institution that was an integral part of such a college or university before November 14, 1986.

“Minority institutions”, as used in this clause, means an institution of higher education meeting the requirements of section 1046(3) of the Higher Education Act of 1965 (20 U.S.C. 1135d-5(3)) which for the purposes of this clause includes a Hispanic-serving institution of higher education as defined in section 316(b)(1) of the Act (20 U.S.C. 1059c(b)(1)).

“Small disadvantaged business concern”, as used in this clause, means a small business concern that (1) is at least 51 percent unconditionally owned by one or more individuals who are both socially and economically disadvantaged, or a publicly owned business having at least 51 percent of its stock unconditionally owned by one or more socially and economically disadvantaged individuals, and (2) has its management and daily business controlled by one or more such individuals. This term also means a small business concern that is at least 51 percent unconditionally owned by an economically disadvantaged Indian tribe or Native Hawaiian Organization, or a publicly owned business having at least 51 percent of its stock unconditionally owned by one or more of these entities, which has its management and daily business controlled by members of an economically disadvantaged Indian tribe or Native Hawaiian Organization, and which meets the requirements of 13 CFR 124.

“Women-owned small business concern”, as used in this clause, means a small business concern (1) which is at least 51 percent owned by one or more women or, in the case of any publicly owned business, at least 51 percent of the stock of which is owned by one or more women, and (2) whose management and daily business operations are controlled by one or more women.

(b) The NASA Administrator is required by statute to establish annually a goal to make available to small disadvantaged business concerns, Historically Black Colleges and Universities, minority institutions, and women-owned small business concerns, at least 8 percent of NASA's procurement dollars under prime contracts or subcontracts awarded in support of authorized programs, including the space station by the time operational status is obtained.

(c) The contractor hereby agrees to assist NASA in achieving this goal by using its best efforts to award subcontracts to such entities to the fullest extent consistent with efficient contract performance.

(d) Contractors acting in good faith may rely on written representations by their subcontractors regarding their status as small disadvantaged business concerns, Historically Black Colleges and Universities, minority institutions, and women-owned small business concerns.

(End of clause)

I.7 ACCESS TO SENSITIVE INFORMATION (1852.237-72) (JUN 2005)

(a) As used in this clause, ``sensitive information'' refers to information that a contractor has developed at private expense, or that the Government has generated that qualifies for an exception to the Freedom of Information Act, which is not currently in the public domain, and which may embody trade secrets or commercial or financial information, and which may be sensitive or privileged.

(b) To assist NASA in accomplishing management activities and administrative functions, the Contractor shall provide the services specified elsewhere in this contract.

(c) If performing this contract entails access to sensitive information, as defined above, the Contractor agrees to--

(1) Utilize any sensitive information coming into its possession only for the purposes of performing the services specified in this contract, and not to improve its own competitive position in another procurement.

(2) Safeguard sensitive information coming into its possession from unauthorized use and disclosure.

(3) Allow access to sensitive information only to those employees that need it to perform services under this contract.

(4) Preclude access and disclosure of sensitive information to persons and entities outside of the Contractor's organization.

(5) Train employees who may require access to sensitive information about their obligations to utilize it only to perform the services specified in this contract and to safeguard it from unauthorized use and disclosure.

(6) Obtain a written affirmation from each employee that he/she has received and will comply with training on the authorized uses and mandatory protections of sensitive information needed in performing this contract.

(7) Administer a monitoring process to ensure that employees comply with all reasonable security procedures, report any breaches to the Contracting Officer, and implement any necessary corrective actions.

(d) The Contractor will comply with all procedures and obligations specified in its Organizational Conflicts of Interest Avoidance Plan, which this contract incorporates as a compliance document.

(e) The nature of the work on this contract may subject the Contractor and its employees to a variety of laws and regulations relating to ethics, conflicts of interest, corruption, and other criminal or civil matters relating to the award and administration of government contracts. Recognizing that this contract establishes a high standard of accountability and trust, the Government will carefully review the Contractor's performance in relation to the mandates and restrictions found in these laws and regulations. Unauthorized uses or disclosures of sensitive information may result in termination of this contract for default, or in debarment of the Contractor for serious misconduct affecting present responsibility as a government contractor.

(f) The Contractor shall include the substance of this clause, including this paragraph (f), suitably modified to reflect the relationship of the parties, in all subcontracts that may involve access to sensitive information

(End of clause)

I.8 RELEASE OF SENSITIVE INFORMATION (JUNE 2005) (1852.237-73)

(a) As used in this clause, “sensitive information” refers to information, not currently in the public domain, that the Contractor has developed at private expense, that may embody trade secrets or commercial or financial information, and that may be sensitive or privileged.
(b) In accomplishing management activities and administrative functions, NASA relies heavily on the support of various service providers. To support NASA activities and functions, these service providers, as well as their subcontractors and their individual employees, may need access to sensitive information submitted by the Contractor under this contract. By submitting this proposal or performing this contract, the Contractor agrees that NASA may release to its service providers, their subcontractors, and their individual employees, sensitive information submitted during the course of this procurement, subject to the enumerated protections mandated by the clause at 1852.237-72, Access to Sensitive Information.
(c)(1) The Contractor shall identify any sensitive information submitted in support of this proposal or in performing this contract. For purposes of identifying sensitive information, the Contractor may, in

addition to any other notice or legend otherwise required, use a notice similar to the following:
Mark the title page with the following legend:
This proposal or document includes sensitive information that NASA shall not disclose outside the Agency and its service providers that support management activities and administrative functions. To gain access to this sensitive information, a service provider's contract must contain the clause at NFS 1852.237-72, Access to Sensitive Information. Consistent with this clause, the service provider shall not duplicate, use, or disclose the information in whole or in part for any purpose other than to perform the services specified in its contract. This restriction does not limit the Government's right to use this information if it is obtained from another source without restriction. The information subject to this restriction is contained in pages [insert page numbers or other identification of pages].
Mark each page of sensitive information the Contractor wishes to restrict with the following legend:
Use or disclosure of sensitive information contained on this page is subject to the restriction on the title page of this proposal or document.
(2) The Contracting Officer shall evaluate the facts supporting any claim that particular information is "sensitive." This evaluation shall consider the time and resources necessary to protect the information in accordance with the detailed safeguards mandated by the clause at 1852.237-72, Access to Sensitive Information. However, unless the Contracting Officer decides, with the advice of Center counsel, that reasonable grounds exist to challenge the Contractor's claim that particular information is sensitive, NASA and its service providers and their employees shall comply with all of the safeguards contained in paragraph (d) of this clause.
(d) To receive access to sensitive information needed to assist NASA in accomplishing management activities and administrative functions, the service provider must be operating under a contract that contains the clause at 1852.237-72, Access to Sensitive Information. This clause obligates the service provider to do the following:
(1) Comply with all specified procedures and obligations, including the
Organizational Conflicts of Interest Avoidance Plan, which the contract has incorporated as a compliance document.
(2) Utilize any sensitive information coming into its possession only for the purpose of performing the services specified in its contract.
(3) Safeguard sensitive information coming into its possession from unauthorized use and disclosure.
(4) Allow access to sensitive information only to those employees that need it to perform services under its contract.
(5) Preclude access and disclosure of sensitive information to persons and entities outside of the service provider's organization.
(6) Train employees who may require access to sensitive information about their obligations to utilize it only to perform the services specified in its contract and to safeguard it from unauthorized use and disclosure.
(7) Obtain a written affirmation from each employee that he/she has received and will comply with training on the authorized uses and mandatory protections of sensitive information needed in performing this contract.
(8) Administer a monitoring process to ensure that employees comply with all reasonable security procedures, report any breaches to the Contracting Officer, and implement any necessary corrective actions.
(e) When the service provider will have primary responsibility for operating an information technology system for NASA that contains sensitive information, the service provider's contract shall include the clause at 1852.204-76, Security Requirements for Unclassified Information Technology Resources. The

Security Requirements clause requires the service provider to implement an Information Technology Security Plan to protect information processed, stored, or transmitted from unauthorized access, alteration, disclosure, or use. Service provider personnel requiring privileged access or limited privileged access to these information technology systems are subject to screening using the standard National Agency Check (NAC) forms appropriate to the level of risk for adverse impact to NASA missions. The Contracting Officer may allow the service provider to conduct its own screening, provided the service provider employs substantially equivalent screening procedures.
(f) This clause does not affect NASA's responsibilities under the Freedom of Information Act.
(g) The Contractor shall insert this clause, including this paragraph (g), suitably modified to reflect the relationship of the parties, in all subcontracts that may require the furnishing of sensitive information.

(End of clause)

SECTION J OF NNK12427240R
LIST OF ATTACHMENTS

J.1 LIST OF ATTACHMENTS

The following attachments constitute part of this contract:

Attachment	Description	Date	No. of Pages
A	Statement of Work (SOW)	February 29, 2012	25
B	Technical Specification	February 29, 2012	50
C	Deliverable Items List and Schedule (DILS)	February 29, 2012	4
D	RESOLVE Background Information Presentation IAC-11-A5DD.1.4	October 2011	30
E	RESOLVE Background Information Paper IAC-11-A5.1.4	October 2011	11
F	Small Business Subcontracting Plan	To Be Submitted With Proposal	TBP
G	Quality Assurance Plan	To Be Submitted With Proposal	TBP
H	Safety and Health Plan	To Be Submitted With Proposal	TBP

(End of clause)

SECTION K OF NNK12427240R

REPRESENTATIONS, CERTIFICATIONS AND OTHER STATEMENTS

K.1 CERTIFICATION AND DISCLOSURE REGARDING PAYMENTS TO INFLUENCE CERTAIN FEDERAL TRANSACTIONS (52.203-11) (SEP 2007)

K.2 WOMEN-OWNED BUSINESS (OTHER THAN SMALL BUSINESS) (52.204-5) (MAY 1999)

K.3 ANNUAL REPRESENTATIONS AND CERTIFICATIONS (52.204-8)(MAR 2012)

(a)

(1) The North American Industry classification System (NAICS) code for this acquisition is **541712.**

(2) The small business size standard is **500.**

(3) The small business size standard for a concern which submits an offer in its own name, other than on a construction or service contract, but which proposes to furnish a product which it did not itself manufacture, is 500 employees.

(b)

(1) If the clause at 52.204-7, Central Contractor Registration, is included in this solicitation, paragraph (d) of this provision applies.

(2) If the clause at 52.204-7 is not included in this solicitation, and the offeror is currently registered in CCR, and has completed the ORCA electronically, the offeror may choose to use paragraph (d) of this provision instead of completing the corresponding individual representations and certification in the solicitation. The offeror shall indicate which option applies by checking one of the following boxes:

[_] (i) Paragraph (d) applies.

[_] (ii) Paragraph (d) does not apply and the offeror has completed the individual representations and certifications in the solicitation.

(c)

(1) The following representations or certifications in ORCA are applicable to this solicitation as indicated:

(i) 52.203-2, Certificate of Independent Price Determination. This provision applies to solicitations when a firm-fixed-price contract or fixed-price contract with economic price adjustment is contemplated, unless—

(A) The acquisition is to be made under the simplified acquisition procedures in Part 13;

(B) The solicitation is a request for technical proposals under two-step sealed bidding procedures; or

(C) The solicitation is for utility services for which rates are set by law or regulation.

(ii) 52.203-11, Certification and Disclosure Regarding Payments to Influence Certain Federal Transactions. This provision applies to solicitations expected to exceed $150,000.

(iii) 52.204-3, Taxpayer Identification. This provision applies to solicitations that do not include the clause at 52.204-7, Central Contractor Registration.

(iv) 52.204-5, Women-Owned Business (Other Than Small Business). This provision applies to solicitations that—

(A) Are not set aside for small business concerns;

(B) Exceed the simplified acquisition threshold; and

(C) Are for contracts that will be performed in the United States or its outlying areas.

(v) 52.209-2, Prohibition on Contracting with Inverted Domestic Corporations—Representation. This provision applies to solicitations using funds appropriated in fiscal years 2008, 2009, or 2010.

(vi) 52.209-5; Certification Regarding Responsibility Matters. This provision applies to solicitations where the contract value is expected to exceed the simplified acquisition threshold.

(vii) 52.214-14, Place of Performance--Sealed Bidding. This provision applies to invitations for bids except those in which the place of performance is specified by the Government.

(viii) 52.215-6, Place of Performance. This provision applies to solicitations unless the place of performance is specified by the Government.

(ix) 52.219-1, Small Business Program Representations (Basic & Alternate I). This provision applies to solicitations when the contract will be performed in the United States or its outlying areas.

(A) The basic provision applies when the solicitations are issued by other than DoD, NASA, and the Coast Guard.

(B) The provision with its Alternate I applies to solicitations issued by DoD, NASA, or the Coast Guard.

(x) 52.219-2, Equal Low Bids. This provision applies to solicitations when contracting by sealed bidding and the contract will be performed in the United States or its outlying areas.

(xi) 52.222-22, Previous Contracts and Compliance Reports. This provision applies to solicitations that include the clause at 52.222-26, Equal Opportunity.

(xii) 52.222-25, Affirmative Action Compliance. This provision applies to solicitations, other than those for construction, when the solicitation includes the clause at 52.222-26, Equal Opportunity.

(xiii) 52.222-38, Compliance with Veterans' Employment Reporting Requirements. This provision applies to solicitations when it is anticipated the contract award will exceed the simplified acquisition threshold and the contract is not for acquisition of commercial items.

(xiv) 52.223-1, Biobased Product Certification. This provision applies to solicitations that require the delivery or specify the use of USDA-designated items; or include the clause at 52.223-2, Affirmative Procurement of Biobased Products Under Service and Construction Contracts.

(xv) 52.223-4, Recovered Material Certification. This provision applies to solicitations that are for, or specify the use of, EPA- designated items.

(xvi) 52.225-2, Buy American Act Certificate. This provision applies to solicitations containing the clause at 52.225-1.

(xvii) 52.225-4, Buy American Act--Free Trade Agreements--Israeli Trade Act Certificate. (Basic, Alternates I, II, and III.) This provision applies to solicitations containing the clause at 52.225- 3.

(A) If the acquisition value is less than $25,000, the basic provision applies.

(B) If the acquisition value is $25,000 or more but is less than $50,000, the provision with its Alternate I applies.

(C) If the acquisition value is $50,000 or more but is less than $77,494, the provision with its Alternate II applies.

(D) If the acquisition value is $77,494 or more but is less than $100,000, the provision with its Alternate III applies.

(xviii) 52.225-6, Trade Agreements Certificate. This provision applies to solicitations containing the clause at 52.225-5.

(xix) 52.225-20, Prohibition on Conducting Restricted Business Operations in Sudan--Certification. This provision applies to all solicitations.

(xx) 52.225-25, Prohibition on Contracting with Entities Engaging in Sanctioned Activities Relating to Iran—Representation and Certification. This provision applies to all solicitations.

(xxi) 52.226-2, Historically Black College or University and Minority Institution Representation. This provision applies to—

(A) Solicitations for research, studies, supplies, or services of the type normally acquired from higher educational institutions; and

(B) For DoD, NASA, and Coast Guard acquisitions, solicitations that contain the clause at 52.219-23, Notice of Price Evaluation Adjustment for Small Disadvantaged Business Concerns.

(2) The following certifications are applicable as indicated by the Contracting Officer:

___ (i) 52.219-22, Small Disadvantaged Business Status.

___ (A) Basic.

___ (B) Alternate I.

___ (ii) 52.222-18, Certification Regarding Knowledge of Child Labor for Listed End Products.

___ (iii) 52.222-48, Exemption from Application of the Service Contract Act to Contracts for Maintenance, Calibration, or Repair of Certain Equipment Certification.

___ (iv) 52.222-52 Exemption from Application of the Service Contract Act to Contracts for Certain Services--Certification.

___ (v) 52.223-9, with its Alternate I, Estimate of Percentage of Recovered Material Content for EPA-Designated Products (Alternate I only).

___ (vi) 52.227-6, Royalty Information.

___ (A) Basic.

___ (B) Alternate I.

_X__ (vii) 52.227-15, Representation of Limited Rights Data and Restricted Computer Software.

(d) The offeror has completed the annual representations and certifications electronically via the Online Representations and Certifications Application (ORCA) website accessed through https://www.acquisition.gov . After reviewing the ORCA database information, the offeror verifies by submission of the offer that the representations and certifications currently posted electronically that apply to this solicitation as indicated in paragraph (c) of this provision have been entered or updated within the last 12 months, are current, accurate, complete, and applicable to this solicitation (including the business size standard applicable to the NAICS code referenced for this solicitation), as of the date of this offer and are incorporated in this offer by reference (see FAR 4.1201); except for the changes identified below *[offeror to insert changes, identifying change by clause number, title, date]*. These amended representation(s) and/or certification(s) are also incorporated in this offer and are current, accurate, and complete as of the date of this offer.

FAR Clause	Title	Date	Change

Any changes provided by the offeror are applicable to this solicitation only, and do not result in an update to the representations and certifications posted on ORCA.

(End of Provision)

K.4 INFORMATION REGARDING RESPONSIBILITY MATTERS (52.209-7) (FEB 2012)

(a) *Definitions*. As used in this provision—"Administrative proceeding" means a non-judicial process that is adjudicatory in nature in order to make a determination of fault or liability (*e.g.*, Securities and Exchange Commission Administrative Proceedings, Civilian Board of Contract Appeals Proceedings, and Armed Services Board of Contract Appeals Proceedings). This includes administrative proceeding at the Federal and State level but only in connection with performance of a Federal contract or grant. It does not include agency actions such as contract audits, site visits, corrective plans, or inspection of deliverables.

"Federal contracts and grants with total value greater than $10,000,000" means—

(1) The total value of all current, active contracts and grants, including all priced options; and

(2) The total value of all current, active orders including all priced options under indefinite-delivery, indefinite-quantity, 8(a), or requirements contracts (including task and delivery and multiple-award Schedules).

"Principal" means an officer, director, owner, partner, or a person having primary management or supervisory responsibilities within a business entity (*e.g.*, general manager; plant manager; head of a division or business segment; and similar positions).

(b) The offeror [_] has [_] does not have current active Federal contracts and grants with total value greater than $10,000,000.

(c) If the offeror checked "has" in paragraph (b) of this provision, the offeror represents, by submission of this offer, that the information it has entered in the Federal Awardee Performance and Integrity Information System (FAPIIS) is current, accurate, and complete as of the date of submission of this offer with regard to the following information:

(1) Whether the offeror, and/or any of its principals, has or has not, within the last five years, in connection with the award to or performance by the offeror of a Federal contract or grant, been the subject of a proceeding, at the Federal or State level that resulted in any of the following dispositions:

(i) In a criminal proceeding, a conviction.

(ii) In a civil proceeding, a finding of fault and liability that results in the payment of a monetary fine, penalty, reimbursement, restitution, or damages of $5,000 or more.

(iii) In an administrative proceeding, a finding of fault and liability that results in—

(A) The payment of a monetary fine or penalty of $5,000 or more; or

(B) The payment of a reimbursement, restitution, or damages in excess of $100,000.

(iv) In a criminal, civil, or administrative proceeding, a disposition of the matter by consent or compromise with an acknowledgment of fault by the Contractor if the proceeding could have led to any of the outcomes specified in paragraphs (c)(1)(i), (c)(1)(ii), or (c)(1)(iii) of this provision.

(2) If the offeror has been involved in the last five years in any of the occurrences listed in (c)(1) of this provision, whether the offeror has provided the requested information with regard to each occurrence.

(d) The offeror shall post the information in paragraphs (c)(1)(i) through (c)(1)(iv) of this provision in FAPIIS as required through maintaining an active registration in the Central Contractor Registration database via https://www.acquisition.gov (see 52.204-7).

(End of provision)TRIP

K.5 REPRESENTATION OF LIMITED RIGHTS DATA AND RESTRICTED COMPUTER SOFTWARE (52.227-15) (DEC 2007)

a) This solicitation sets forth the Government's known delivery requirements for data (as defined in the clause at 52.227-14, Rights in Data--General). Any resulting contract may also provide the Government the option to order additional data under the Additional Data Requirements clause at 52.227-16, if included in the contract. Any data delivered under the resulting contract will be subject to the Rights in Data--General clause at 52.227-14 included in this contract. Under the latter clause, a Contractor may withhold from delivery data that qualify as limited rights data or restricted computer software, and deliver form, fit, and function data instead. The latter clause also may be used with its Alternates II and/or III to obtain delivery of limited rights data or restricted computer software, marked with limited rights or restricted rights notices, as appropriate. In addition, use of Alternate V with this latter clause provides the Government the right to inspect such data at the Contractor's facility.

(b) By completing the remainder of this paragraph, the offeror represents that it has reviewed the requirements for the delivery of technical data or computer software and states [*offeror check appropriate block*]—

[ ] (1) None of the data proposed for fulfilling the data delivery requirements qualifies as limited rights data or restricted computer software; or

[ ] (2) Data proposed for fulfilling the data delivery requirements qualify as limited rights data or restricted computer software and are identified as follows:

____

____

____

(c) Any identification of limited rights data or restricted computer software in the offeror's response is not determinative of the status of the data should a contract be awarded to the offeror.

(End of provision)

SECTION L OF NNK12427240R

INSTRUCTIONS, CONDITIONS AND NOTICES TO OFFERORS

L.1 SUBMISSION OF OFFERS IN THE ENGLISH LANGUAGE (52.214-34) (APR 1991)

L.2 SUBMISSION OF OFFERS IN U.S. CURRENCY (52.214-35) (APR 1991)

L.3 INSTRUCTIONS TO OFFERORS - COMPETITIVE ACQUISITION (52.215-1) (JAN 2004)

L.4 REQUESTS FOR WAIVER OF RIGHTS TO INVENTIONS (1852.227-71) (APR 1984)

L.5 PATENT RIGHTS CLAUSES (1852.227-84) (DEC 1989)

L.6 TYPE OF CONTRACT (52.216-1) (APR 1984)

The Government contemplates award of a **FIRM FIXED PRICE** contract resulting from this solicitation.

L.7 SERVICE OF PROTEST (52.233-2) (SEP 2006)

(a) Protests, as defined in section 33.101 of the Federal Acquisition Regulation, that are filed directly with an agency, and copies of any protests that are filed with the Government Accountability Office (GAO), shall be served on the Contracting Officer (addressed as follows) by obtaining written and dated acknowledgment of receipt from:

NASA John F. Kennedy Space Center
ATTN: Chelsea M. Poling
Mail Code: OP-MS
Kennedy Space Center, FL 32899

(b) The copy of any protest shall be received in the office designated above within one day of filing a protest with the GAO.

L.8 PROTESTS TO NASA (1852.233-70) (OCT 2002)

Potential bidders or offerors may submit a protest under 48 CFR Part 33 (FAR Part 33) directly to the Contracting Officer. As an alternative to the Contracting Officer's consideration of a protest, a potential bidder or offeror may submit the protest to the Assistant Administrator for Procurement, who will serve as or designate the official responsible for conducting an independent review. Protests requesting an independent review shall be addressed to Assistant Administrator for Procurement, NASA Code H, Washington, DC 20546-0001.

L.9 SAFETY AND HEALTH PLAN (1852.223-73) (NOV 2004)

(a) The offeror shall submit a detailed safety and occupational health plan as part of its proposal (see NPR 8715.3, NASA Safety Manual, Appendices). The plan shall include a detailed discussion of the policies, procedures, and techniques that will be used to ensure the safety and occupational health of Contractor employees and to ensure the safety of all working conditions throughout the performance of the contract.

(b) When applicable, the plan shall address the policies, procedures, and techniques that will be used to ensure the safety and occupational health of the public, astronauts and pilots, the NASA workforce (including Contractor employees working on NASA contracts), and high value equipment and property.

(c) The plan shall similarly address subcontractor employee safety and occupational health for those proposed subcontracts that contain one or more of the following conditions:

(1) The work will be conducted completely or partly on premises owned or controlled by the Government.

(2) The work includes construction, alteration, or repair of facilities in excess of the simplified acquisition threshold.

(3) The work, regardless of place of performance, involves hazards that could endanger the public, astronauts and pilots, the NASA workforce (including Contractor employees working on NASA contracts), or high value equipment or property, and the hazards are not adequately addressed by Occupational Safety and Health Administration (OSHA) or Department of Transportation (DOT) regulations (if applicable).

(4) When the assessed risk and consequences of a failure to properly manage and control the hazard(s) warrants use of the clause.

(d) This plan, as approved by the Contracting Officer, will be included in any resulting contract.

(End of provision)

L.10 DELIVERY INSTRUCTIONS FOR BIDS/PROPOSALS (KSC 52.214-90) (AUG 2005)

(a) Delivery Address:
All offers (bids or proposals) shall be delivered to the Central Industry Assistance Office (CIAO), 7110 N. Courtenay Parkway, Merritt Island, FL, 32953 on or before the date and time set for receipt of proposals or bids. The CIAO is located on State Road 3, approximately 2 miles south of Gate 2 to KSC. Access to KSC is not required.

(b) Hand-Delivered Offers:
Offerors are responsible for assuring that hand-carried bids are received by NASA Government employees at the CIAO.

(c) Late Delivery of Offers/Bids
Late offers/bids will be processed in accordance with FAR 52.214-7, Late Submissions, Modifications and Withdrawals of Bids, FAR 52.215-1, Instructions to Offerors - Competitive Acquisition, FAR 52.212-1 Instructions to Offerors - Commercial Items, or FAR 52.214-23, Late Submissions, Modifications, and Withdrawals of Technical Proposals Under Two Step Sealed Bidding, included in this solicitation.

(d) Submission of Proposal
Proposals shall be submitted in a sealed envelope or package in accordance with FAR 52.215-1, Instructions to Offerors – Competitive Acquisition.

(End of Provision)

L.11 PROPOSAL MARKING

All proposal packages must be closed and sealed.

The proposal package must include the offeror's name and return mailing address.

L.12 COMMUNICATIONS REGARDING THIS SOLICITATION

The Government will answer relevant and appropriate questions regarding this solicitation. Written questions regarding this request for proposal may be submitted on or before **May 8, 2012**. Questions received by that date will be answered in writing. Questions received after that date will be considered, but may not be answered at the sole discretion of the Contracting Officer. Since answers and associated questions are provided to all Offerors eligible for award, questions should not include any perceived proprietary or sensitive information that the questioner does not wish to be disclosed to other Offerors. Questions must be e-mailed to Chelsea M. Poling at chelsea.poling@nasa.gov

L.13 PROPOSAL PREPARATIONS –GENERAL INSTRUCTIONS

It is NASA's intent, by providing the instructions set forth below, to solicit information that will demonstrate the offeror's competence to successfully complete the requirements specified in this Request for Proposal (RFP). Generally, the proposal should:

- Demonstrate understanding of the overall and specific requirements of the proposed contract.
- Convey the company's capabilities for transforming understanding into accomplishment.
- Present in detail, the plans and methods for so doing.

In the event that other organizations are proposed as being involved in conducting this work, their relationships during the effort shall be explained and their proposed contributions shall be identified and integrated into each part of the proposal, as appropriate.

(a) PROPOSAL FORMAT AND ORGANIZATION

(1)Offerors shall submit proposals in two volumes as specified below:

Volume	**Title**	**Copies**
I	Technical and Management Approach Volume	Original Plus 6 Hard Copies and Two Electronic Copies
II	Business Proposal	Original Plus 6 Hard Copies and Two Electronic Copies

(2) All pages of Volumes I and II shall be numbered and identified with the offeror's name, RFP number and date. Subsequent revisions, if requested, shall be similarly identified to show revision number and date. A table of contents shall be provided with figures and tables listed separately.

(3) Two electronic copies of the offeror's proposal, designating one as "back-up," shall be submitted (in addition to the hardcopies specified above) in Microsoft Word and Excel for Windows. Price proposal charts shall use Microsoft Excel for Windows. Electronic files of Volumes I and II shall be on virus free CD-ROM (CD-R format) discs with an external label indicating: (1) the name of the offeror, (2) the RFP number, (3) the format and software versions used, (4) a list of the files contained on the disk and (5) date of the information. In the event of any inconsistency between data provided on electronic media and hard copies, the hard copy data will be considered to be correct.

(4) The format for each proposal volume shall parallel, to the greatest extent possible, the format of the evaluation factors and subfactors contained in Section M of this solicitation. The proposal content shall provide a basis for evaluation against the requirements of the solicitation. Each volume of the proposal shall specify the relevant evaluation criteria being addressed, if appropriate. The proposal shall include a matrix showing where in the proposal the technical requirements of the SOW and Specification of this RFP are satisfied (i.e. SOW/Specification elements versus offeror's proposal page numbers). It is intended that this be a simple matrix that should in no way inhibit an innovative approach or burden the offeror. This proposal matrix is excluded from the page limitations contained in paragraph (b)(1) below.

(5) Information shall be precise, factual, detailed and complete. Offerors shall not assume that the evaluation team is aware of company abilities, capabilities, plans, facilities, organization or any other pertinent fact that is important to accomplishment of the work as specified in the SOW. The evaluation will be based primarily on the information presented in the written proposal. The proposal shall specifically address each listed evaluation factor and subfactor.

(b) PROPOSAL CONTENT AND PAGE LIMITATIONS

(1) The following table contains the page limitations for each portion of the proposal submitted in response to this solicitation. Additional instructions for each component of the proposal are located in the contract provision noted under the Reference heading.

Proposal Component	Volume	Reference	Page Limitations
<u>Technical and Management Approach Volume</u>	I	**L.14**	75 Pages
(a) Cover Page, Indices, SOW/Specification Compliance Matrix, Quality Assurance Plan, Safety and Health Plan, and Small Business Utilization Subfactor			Excluded
(b) Deviations & Exceptions			Excluded
<u>Business Proposal Volume</u>	II	**L.15**	
(a) (Standard Form (SF) - 33 and Sections B-J of Model Contract including Representations and Certifications)			
(b) Price Proposal			None
(c) Past Performance			
(a) Information from the offeror			<u>10 pages total</u>

Proposal Component	Volume	Reference	Page Limitations
(b) Cover Page, Indices and List of Acronyms			Excluded
(c) Deviations & Exceptions			Excluded

(2)A page is defined as one side of a sheet, 8-1/2" x 11", with at least one inch margins on all sides, using not smaller than 12 point type Times New Roman font. Line spacing or the amount of vertical space between lines of text shall not be less than single line (Microsoft Word's default line spacing). Character spacing shall be "Normal", not "Expanded" or "Condensed." The margins may contain headers and footers, but shall not contain any proposal content to be evaluated. Foldouts count as an equivalent number of 8-1/2" x 11" pages. The metric standard format most closely approximating the described standard 8-1/2" x 11" size may also be used.

Volumes I and II shall be submitted in separate ringed (or similarly bound) binders. Diagrams, tables, artwork, and photographs may be reduced and, if necessary, run landscape or folded to eliminate oversize pages. Text in Diagrams, schedules, charts, tables, artwork, and photographs shall be no smaller than 10 point. Diagrams, tables, artwork, and photographs shall not be used to circumvent the text size limitations of the proposal.

(3) Title pages, tabs, and tables of contents are excluded from the page counts specified in paragraph (1) of this provision (as well as other documents specified in table (b)(1) above). In addition, the Price volume of your proposal is not page limited. However, this volume is to be strictly limited to cost and price information. Information that can be construed as belonging in one of the other volumes of the proposal will be so construed and counted against that volume's page limitation.

(4) The Government intends to evaluate proposals and award contract(s) without discussions with offerors (except clarifications as described in FAR 15.306(a)). Therefore, the offeror's initial proposal should contain the offeror's best terms from a cost or price and technical standpoint. The Government reserves the right to conduct discussions if the Contracting Officer later determines them to be necessary. If discussions are held and final proposal revisions are requested, the Government will specify separate page limitations in its request for that submission.

(5) Pages submitted in excess of the limitations specified in this provision will not be evaluated by the Government and will be returned to the offeror in accordance with NFS 1815.204-70(b).

(End of provision)

L.14 TECHNICAL AND MANGEMENT APPROACH PROPOSAL INSTRUCTIONS

This must be a separate volume.

Contents of Technical and Management Approach Proposal Instructions

1. General Instructions
2. Technical and Management Approach Volume Format
3. Technical and Management Approach Instructions by Subfactor

1. General Instructions

The Technical and Management Approach Proposal should be specific, detailed, and provide all the information requested by these instructions. The Technical and Management Approach Proposal must demonstrate that the offeror understands the requirements and has the ability to meet the requirements. General statements such as the "requirements are understood" or "standard procedures will be employed" are not adequate. Also, restatement or paraphrasing of the requirements should be avoided. Information previously submitted, if any, will be not be considered unless it is resubmitted as part of the proposal. It must not be incorporated by reference.

2. Technical and Management Approach Volume Format

The Technical and Management Approach Proposal must be divided and presented by each Technical and Management Approach subfactor as follows:

Subfactor A--Technical Approach
Subfactor B--Key Personnel
Subfactor C--Small Business Utilization
Subfactor D--Safety and Health Plan

3. Technical and Management Approach Instructions by Subfactor

SUBFACTOR A--TECHNICAL APPROACH

The offeror shall provide a technical approach that demonstrates an understanding of the technical requirements of the Statement of Work, Specification, and Deliverable Items List and Schedule. The offeror shall also include a compliance matrix that lists or references all requirements from the SOW and Specification. The matrix shall include a comments field that indicates that the offeror is compliant with each requirement as a result of either the current technical implementation or how the offeror intends to meet the requirements. In addition, the matrix shall provide a cross-reference to the location in the proposal where compliance is proposed. Where existing hardware has demonstrated the capability to meet the performance requirements, supporting data shall be provided. For performance requirements that have not been demonstrated, describe the path to meet the performance requirements.

The technical approach shall address the following critical performance characteristics in enough detail to clearly and fully demonstrate that the offeror thoroughly understands these requirements. Further, the offeror shall address any innovative design and/or unique approach to the following performance related requirements:

- Demonstrate that you have experience in analytical instrumentation including mechanical engineering, software, electronics, and scientific understanding of instrumentation.
- Describe system modeling capabilities to fully understand design considerations (Modeling can include thermal, electrical, ion trajectories, and mechanical.)
- Demonstrate detailed knowledge of and experience in GC-MS architecture, column design, GC-to-MS interface, including direct injection into MS as backup if GC is not available.
- Provide a discussion of the challenges that water analysis presents, and a description of the contractor’s technical approach for GC-MS water detection and verification of instrument accuracy for water analysis.
- Provide details and any experience on vacuum operation of similar instruments with respect to thermal control of components and effects on GC and MS operation.
- Provide details on how you propose to verify the performance of the instrument.
- Provide a parts and material flow diagram. Provide a fabrication and assembly plan which describes in detail each step in the process, including repair procedures.
- Identify critical and high-risk areas in the design, fabrication, and assembly process and discuss proposed actions, solutions, or technical approach to manage these risks.
- Discuss the heritage of the proposed design.

The offeror shall describe how performance and functional testing to meet the standards specified in the SOW and Specification will be achieved. Additionally, each test's environmental conditions shall be detailed. Where not specified in the SOW or Specification, the offeror shall describe the standards and conditions under which each test will be performed.

The offeror shall provide information that to the extent possible demonstrates flight heritage for the proposed instrument design. In addition, the offeror shall include a reliability assessment of the design with supporting test data. Where supporting test data is not available, the offeror shall provide a description of the analysis or testing that will be performed to demonstrate suitability for the RESOLVE mission application.

The offeror shall prepare and submit with the proposal a time-phased activity and milestone schedule depicting the critical elements/span of design, development, fabrication, assembly, inspection, and test, as well as significant procurement events to meet the contract delivery schedule. This schedule shall not be altered, except to depict progress against it.

In addition, the offeror's plan shall identify and discuss the risk factors associated with accomplishment of the requirements of the contemplated contract. Risk factors may be those inherent in the work, unique to the offeror's chosen approach, and must include any risk factors that are specifically identified by the Government in this solicitation. General areas of possible risk that are of concern to NASA are technical, schedule, cost, safety, occupational health, security (including personnel, information technology, sensitive information disclosure), export control and environmental risks. The identification of risks is the responsibility of the offeror. However, these instructions may include Government identified risks that the offeror must also address. Each offeror's discussions pertaining to risk factors must address the offeror's approach to managing the risk, the probability of the risk, impact and severity of risk, relevant time impact and risk acceptance or risk mitigation. The offeror's shall also identify any risk areas that may impact the delivery schedule. These areas include any ongoing development efforts or parts, materials, regulatory, or process issues.

The offeror's proposal shall clearly describe all non-standard practices. These would be practices that deviate from specified government or industry standards contained in the SOW. Additionally, the offeror shall provide an explanation and rationale for differences between contractor-specific standards and standards specified in the SOW.

The offeror shall provide a Quality Assurance Plan that implements a Quality Management System that meets the intent of the requirements of American National Standards Institute (ANSI/ISO/American Society for Quality (ASQ) Q9001 (1994 or 2000 version or equivalent).

The offeror's proposal shall describe in detail its overall management approach for the proposed activities. The proposal shall describe the organization and management methods that will be utilized in performing work under the contract and shall also describe plans for interfacing with and facilitating communication with the Government's personnel, including the ability to work with NASA (contract mechanism) to partner in the design.

The offeror's proposal shall describe and demonstrate a facility adequately capable of the fabrication of highly sensitive instrumentation, to include but not limited to system assembly areas such as: electrical testing and integration, clean hardware integration area, and proper safety equipment.

<u>SUBFACTOR B--KEY PERSONNEL</u>
Of the key personnel, identify the Project Manager and discuss the relationships of key personnel positions within the organizational structure. The offeror shall describe their approach to project management. Describe the lines of authority and the internal interactions between key positions and other organizational elements. Describe any proposed interfaces among the key positions and external elements (e.g., subcontractors, Government, other contractors).

Describe the technical expertise and rationale for the mix of the proposed personnel relative to the technical support requirements. Provide the rationale for the descriptions of the key positions identified. Refer to Table L-2 for minimum qualification requirements. Publications, awards, personal references and other appropriate documentation will demonstrate excellence in the following areas:

- Technical competence and experience in technology research, development, evaluation and transition as described in the SOW.
- Experience in delivering products for customer use
- Current involvement in technical community
- Ability to generate and maintain good working relationships with customers and suppliers and to effectively collaborate with other individuals and organizations.

Provide resumes for each key personnel proposed to be employed on the contract. A minimum of one (1) resume for each proposed key personnel classification is required. Resumes shall be presented in the standard format and shall contain the information shown in Table L-1 of this section. “Experience” on resumes shall specifically discuss work experience relevant to the requirements of the labor classification proposed on and shall include specific examples of accomplishments. Experience directly related to current state of the art technologies is highly desirable. General statements of experience will not be accepted.

TABLE L-1
Standard Resume Format

1. Name
2. Current position/Company labor classification
3. Minimum company qualifications to hold position
4. Level of security clearance
5. Contingent employee (yes or no)
6. Education (include degree(s), major, name of university and year degree earned)
7. Experience listed in chronological order from present to past (include company or organization experience obtained from position, position title, duties,

responsibilities and actual quantifiable accomplishments). Identify only experience which is pertinent to the labor classification in which proposed.

8. Professional societies or organization, if applicable
9. Published works, if applicable

TABLE L-2

Contract Proposal Technical Labor Classifications

1. Professional/Technical Classifications
    a. Senior Chemist - Requires a doctoral degree (or equivalent years of experience in the field of specialization) and 10 years of related experience. Requires specialized experience in the field of mass spectrometry, chromatography, and instrument design. Experience in design for space qualified systems is desired.

    b. Senior Physicist- Classification requires a doctoral degree (or equivalent years of experience in the field of specialization) and 10 years of related experience. Requires specialized experience in the field of mass spectrometry (ionization or molecules, ion trajectories, interaction of molecules, and instrument design) with the ability to design and model novel instrument designs.

    c. Senior Mechanical Engineer- Requires a master's degree (or equivalent years of experience in the field of specialization) and 10 years of related experience. Requires specialized experience in the analysis of structures with vibrational, thermal, and mechanical stresses. Experience in design for space qualified systems is desired.

    d. Senior Electrical Engineer - Requires a bachelor's degree (or equivalent years of experience in the field of specialization) and 10 years of related experience. Requires specialized experience in electrical design for analytical instrumentation and experience in designing for vacuum environmental conditions. Experience in design for space qualified systems is desired.

    e. Senior Software Engineer - Requires a bachelor's degree (or equivalent years of experience in the field of specialization) and 10 years of related experience. Requires specialized experience in software design for analytical instrumentation including command and control of systems as well as data processing. Experience in design for space qualified systems is desired.

> Experience in each classification should reflect the ability to do independent problem solving leading to the development of analytical systems or subsystems that are integrated or required for analytical systems.

Propose how administrative functions will be accomplished, i.e., embedded in the duties of key personnel or provided separately. Similarly, discuss other functions necessary for preparation and generation of technical reports and presentations such as technical writing, graphical layouts, printing and publication.

Describe the method for recruiting and staffing of key personnel to meet the requirements of the Statement of Work (SOW). Identify any proposed personnel with the proper skills who are immediately available within your company to accomplish the requirements of this contract. Discuss any proposed recruitment and employment methods and plans for obtaining any additional personnel required to initially staff and/or support this unit. Discuss the flexibility in assignment of personnel with required skills and allocation of resources in order to respond to sudden, unanticipated changes in tasking or priority.

Describe the intent and/or proposed procedures to temporarily replace key personnel during long duration absences (i.e., 4 to 6 weeks), such as extended sick leave, vacations, military leave, etc. Selection/replacement procedures must be discussed when key personnel are permanently replaced due to changes in employment status.

<u>SUBFACTOR C--SMALL BUSINESS UTILIZATION (SBU)</u>

All Offerors, except small businesses, must complete the portion of the instructions under Small Business Subcontracting specific to the Small Business Subcontracting Plan. Small businesses are not required to submit Small Business Subcontracting Plans; however, small businesses are required to indicate the amount of effort proposed to be done by a small business either at the prime level or at the first tier subcontract level.

All Offerors are required to respond to the Commitment to the Small Business Program.

(a) Small Business Subcontracting

(1) <u>Small Business Subcontracting Plan (the Plan) Required by the FAR</u>:

(i) This solicitation contains FAR clause 52.219-9, "Small Business Subcontracting Plan with Alternate II". The Plan described and required by the clause, including the associated subcontracting percentage goals and subcontracting dollars, shall be submitted with your proposal.

(ii) The Contracting Officer's assessment of appropriate subcontracting goals for this acquisition, expressed as a percent of TOTAL CONTRACT VALUE (basic and all options combined), is as follows:

Total Small Businesses (SB)	6.0%
Veteran Owned Small Business Concerns (VOSB)	1.0%
Women Owned Small Business Concerns (WOSB)	0.9%
Service-Disabled Veteran-Owned Small Business Concerns (SDVOSB)	0.7%
Small Disadvantaged Business Concerns (DB)	0.2%
HUBZone Small Business Concerns (HBZ)	0.1%

(iii) The numbers above reflect the Contracting Officer's assessment of the appropriate subcontracting goals to be achieved at the completion of contract performance. If it is anticipated that the proposed small business goals will not be met by the submission of the first Individual Subcontracting Report (ISR) for this effort as required by 52.219-9 Small Business Subcontracting Plan, the Offeror should discuss their approach to include timeline for meeting these goals and the rationale for it.

(iv) Offerors are encouraged to propose goals that are equivalent to or greater than those recommended by the Contracting Officer. However, Offerors must perform an independent assessment of the small business subcontracting opportunities.

(v) The Plan submitted with the proposal shall be incorporated in Section J as Attachment J-F in the resulting contract. The requirements in the Plan must flow down to first tier large business subcontracts expected to exceed $650,000 or $1,500,000 for construction of a public facility. Although these first tier large business subcontractors are encouraged to meet or exceed the stated goals, it is recognized that the subcontracting opportunities available to these subcontractors may differ from those suggested in the solicitation based upon the nature of their respective performance requirements.

(vi) Offerors are advised that a proposal will not be rejected solely because the submitted Plan does not meet the NASA recommended goals that are expressed in paragraph (a) (2) above in terms of percent of TOTAL CONTRACT VALUE (basic and all options combined). NASA will consider the amount of work being retained for performance by the prime contractor in-house when determining whether a subcontracting plan is acceptable. Offerors shall discuss the rationale for any goal proposed that is less than the Contracting Officer's recommended goal in any category. In addition, the Offeror shall describe the efforts made to establish a goal for that category and what ongoing efforts, if any, the Offeror plans during performance to increase participation in that category.

(vii) In addition to submitting a Small Business Subcontracting Plan in accordance with Section I, FAR clause 52.219-9, Alternate II, Offerors shall complete Exhibit X, SMALL BUSINESS SUBCONTRACTING PLAN GOALS, which provides a breakdown of the

Offeror's proposed goals, by small business category, expressed in terms of both a percent of TOTAL CONTRACT VALUE and a percent of TOTAL PLANNED SUBCONTRACTS. Offerors shall modify the exhibit to show the proposed subcontracting goals for the basic contract requirement and each option separately.

Example of Subcontracting Goals, expressed in both contract value and subcontract value, for a contract proposed at $100M with estimated subcontracts of $50M:

	Column A	***Column B***	***Column C***
Business Category	**Goal as Percent of Contract Value**	**Dollar Value to be subcontracted per Category**	**Goal as Percent of Subcontracting Value**
Small Business Concerns	25 percent	$25,000,000	50 percent
Large Business Concerns	n/a	$25,000,000	50 percent
Total Dollars to be Subcontracted	n/a	$50,000,000	100 percent
The following small business subcategories do not necessarily add up to the percentage and dollar amount in the "Small Business Concerns" category above, since some small businesses do not fall into any of the subcategories below, while others will fall into more than one subcategory below.			
Subcategories of Small Business Concerns			
Women Owned Small Business Concerns	9 percent	$9,000,000	18 percent
Small Disadvantaged Business Concerns	5.5 percent	$5,500,000	11 percent
Veteran Owned Small Business Concerns	2.5 percent	$2,500,000	5 percent
Service-Disabled Veteran-Owned Small Business Concerns	1.5 percent	$1,500,000	3 percent
HUBZone Small Business Concerns	1.5 percent	$1,500,000	3 percent
Historically Black Colleges and Universities/Minority Institutions	1.5 percent	$1,500,000	3 percent

It is recommended that Offerors first complete Column B by entering the dollar amount the Offeror proposes to subcontract to each business category and subcategory.

To complete Column A, divide the dollar amount in Column B by the total offered price of the proposal (that is, total contract value). In the example above, Column A for

Veteran Owned Business Concerns = $2,500,000 divided by $100,000,000, or 2.5 percent.

To complete column C, divide the corresponding amount in Column B by the amount in the "Total Dollars to be Subcontracted" cell in Column B. In the example above, Column C for Women-Owned Small Businesses = $9,000,000 divided by $50,000,000, or 18percent.

Note: the "Total Dollars to be Subcontracted" amount in Column C will always be that category divided by itself (100percent if any dollars are subcontracted).

(b) Commitment to the Small Business Program

(1) All Offerors shall briefly describe work that will be performed by small businesses. Proposals should also identify any work to be subcontracted that is considered "high technology." High Technology is defined as research and development efforts that are within or advance the state-of-the-art in technology discipline and are performed primarily by professional engineers, scientists, and highly skilled and trained technicians or specialists.

(2) If the subcontractor(s) is known, Offerors must connect the work to the subcontractor and specify the extent of commitment to use the subcontractor (s) (enforceable vs. non-enforceable commitments). (Small Business Offerors shall provide this information to the extent subcontracting opportunities exist in their approach to performing the requirement.)

(3) All Offerors shall provide information demonstrating the extent of commitment to utilize small business concerns and to support their development. Information provided should include a brief description of established or planned procedures and organizational structure for Small Business outreach, assistance, participation in the Mentor Protégé program, counseling, market research and Small Business identification, and relevant purchasing procedures. For Other than Small (Large) Business Offerors, this information should conform to applicable portions of the submitted Small Business Subcontracting Plan. Small Business Offerors shall provide this information to the extent subcontracting opportunities exist in their approach to performing the requirement.)

(End of provision)

<u>SUBFACTOR D--SAFETY AND HEALTH PLAN</u>

The offeror shall provide a safety and health plan in accordance with NFS Provision 1852.223-73, entitled "Safety and Health Plan". The offeror shall discuss its approach to compliance with all applicable NASA policies and procedures relative to safety, occupational health, and NASA Procedural Requirements (NPR) 8715.3 “NASA General Safety Program Requirements.”

This plan, as approved by the Government, will be included in any resulting contract. Offerors are directed to NPR 8715.3, Appendix E instructions regarding the contents of Safety and Health Plan. NPR 8715.3 can be accessed at the following website:

http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8715&s=3C

The offeror shall indicate if any of the standard contents of the Safety and Health Plan, as prescribed by NPR 8715.3, would not be applicable to this specific contract, and provide an explanation for that determination.

4. Deviations\Exceptions (Technical and Management Approach Proposal)

Identify and explain the reason for any deviations, exceptions, or conditional assumptions taken with respect to these technical and management approach proposal instructions or to any of the technical requirements of this solicitation, such as the statement of work and related specifications.

(End of provision)

L.15 BUSINESS PROPOSAL VOLUME INSTRUCTIONS

This must be a separate volume.

The Business Proposal volume must be divided and presented by each subfactor as follows:

Subfactor A—Offer/Model Contract
Subfactor B—Price
Subfactor C—Past Performance

SUBFACTOR A—OFFER/MODEL CONTRACT

(a) STANDARD FORM (SF) 33, OFFEROR FILL INS AND SECTION K

Blocks 12 through 18 of the SF 33 and the indicated Offeror required fill-ins in Sections B-K must be completed. The signed SF33 and the pages with the required fill-ins must be submitted. Annual representations and certifications shall be completed electronically in accordance with provision K.1, Annual Representations and Certifications (52.204-8).

SECTION L OF NNK12427240R

INSTRUCTIONS, CONDITIONS AND NOTICES TO OFFERORS

The balance of the solicitation need not be returned unless the Offeror has made changes to other pages that will constitute part of the contract. Any such changes must be separately identified in the Summary of Exceptions. All SF 33s require original signatures.

(1) It is requested that Offerors indicate, in Block 12 of the SF 33, a proposal validity period of 120 days. However, in accordance with paragraph (d) of FAR provision 52.215-1, "Instructions to Offerors--Competitive Acquisitions," a different validity period may be proposed by the Offeror.

(2) Provide the names and phone numbers of persons to be contacted for clarification of questions of a technical nature and business nature. Identify any consultants used in writing this proposal (if any) and the extent to which their services will be available in the subsequent performance of this effort.

The contract schedule refers to TBD and TBP. They are defined as follows:

TBD = TO BE DETERMINED BY THE GOVERNMENT
TBP = TO BE PROPOSED BY THE CONTRACTOR

(b) SUMMARY OF EXCEPTIONS

Include a statement of acceptance of the anticipated contract provisions and proposed contract schedule, or list all specific exceptions to the terms, conditions, and requirements of Sections A through J of this solicitation, to the Representations and Certifications (Section K) or to the information requested in Section L. Include the reason for the exception, or refer to where the reason is addressed in the proposal. This list must include all exceptions, both "business" and "technical".

Include any new terms, conditions or clauses proposed by the Offeror which are of benefit to the Government. Discuss the benefit to the Government in Volume I, or II as appropriate.

Offerors are cautioned that exceptions or new terms, conditions, or clauses may result in a determination of proposal unacceptability (NFS 1815.305-70), may preclude award to an Offeror if award is made without discussions, or may otherwise affect an Offeror's competitive standing.

(c) ADDITIONAL INFORMATION TO BE FURNISHED

(1) Contract Administration

Furnish the information listed below:

a. Cognizant Government audit agency with mailing address, email address, telephone number, and fax number.

b. Cognizant Government inspection agency with mailing address, email address, telephone number, and fax number.

c. Cognizant Government Administrative Contracting Officer by name with mailing address, email address, telephone number, and fax number.

(2) Responsibility Information

Provide information addressing all of the elements under FAR 9.104 to demonstrate responsibility (address the elements under this section that are not addressed in another proposal volume).

(3) Taxpayer Identification Number

Prime offerors shall provide their Taxpayer Identification Number (TIN) (the number required by the Internal Revenue Service (IRS) to be used by the offeror in reporting income tax and other returns).

(4) Subcontractor Listing

The Offeror shall provide a summary listing (by name and address) of all subcontractors (regardless of dollar value) that have been identified throughout the Offeror’s proposal and the subcontract value associated with each entity.

(End of provision)

<u>SUBFACTOR B—PRICE PROPOSAL</u>

PRICE PROPOSAL INSTRUCTIONS

The offeror shall complete clauses B.2 and B.3 in the attached model contract in their entirety. Failure to properly complete these clauses may result in the Offeror's proposal being deemed non-responsive and removed from further consideration.

Deviations to the milestone percentage under clause B.3 may result in a determination of proposal unacceptability (NFS 1815.305-70), may preclude award to an offeror if award is made without discussions, or may otherwise affect an offeror's competitive standing.

(End of provision)

SUBFACTOR C—PAST PERFORMANCE

PAST PERFORMANCE INSTRUCTIONS

An Offeror's past performance record indicates the relevant quantitative and qualitative aspects of performing services or delivering products similar in size, content, and/or complexity to the requirements of this acquisition (Refer to FAR 15.305(a)(2)(iii)).

The Offeror shall provide, at a minimum, the following information in support of its proposal to facilitate the evaluation of your company experience and past performance as a whole and as related to the requirements of the proposed contract

(a) *RELEVANT EXPERIENCE/PAST PERFORMANCE*

The offeror shall submit past performance history on **not more than three (3) contracts** that the offeror has deemed most recent and relevant past experience. Recent experience is defined as projects performed currently or in the last five years. Relevant experience is defined as past or current experience managing and performing contracts similar in size, content, and complexity to the requirements of this RFP where characteristics such as technical excellence, responsiveness, safety, communication, and management were successfully implemented.

Offerors shall provide information of relevant contracts, listing (a) all protoflight or flight qualified instruments for which the Offeror was the prime Contractor that have been delivered in the past five years (b) Gas Chromatograph-Mass Spectrometer for which the Offeror is or will be the prime contractor that is currently in the development and implementation phase.

Offerors shall provide information on previous contracts for the Government's evaluation of Experience/Past Performance that includes:

(1) CONTACT INFORMATION: Customer's name, address, email address and telephone number for the Contracting Officer and Technical Representative points of contact. Ensure that the information is current and accurate by verifying the phone numbers and addresses.

(2) BASIC CONTRACT INFORMATION: Contract number, contract type, place(s) of performance, state if the contract was competitive or sole-source, state if the contract was an initial or follow-on contract and if the offeror was the prime contractor or subcontractor.

(3) PERIOD OF PERFORMANCE: Date contract was awarded, original contract period of performance, and actual contract period of performance.

(4) CONTRACT VALUE: The original value of the contract at time of award and the present or final contract value. Provide rationale for any cost growth.

(5) SCHEDULE: The success record in meeting contractual delivery dates, and explanations for any deviations from those dates.

(6) CONTRACT REVISIONS: Give a brief explanation if the contract was descoped or partially terminated for any reason, or if the terms or conditions were significantly restricted for any reason, or if there were any major waivers or deviations granted, or if options were not exercised.

(7) RELEVANCE: Describe how the respective contract is similar in size, content, and complexity to the current requirement. It is not sufficient to state that it is comparable in magnitude and scope. Rationale must be provided to demonstrate that it is comparable.

(8) PERFORMANCE: Describe any relevant major technical problems and how they were resolved.

Offerors are advised that while the list of submitted contracts/orders are at the offeror's discretion, the Government may consider and evaluate any other past performance data obtained from other sources and use the obtained information in the evaluation and rating of the offerors past performance.

(b) *SUMMARY OF DEVIATIONS/EXCEPTIONS (PAST PERFORMANCE PROPOSAL)*

Identify and explain the reason for any deviations, exceptions, or conditional assumptions taken with respect to these Past Performance Proposal instructions.

(End of provision)

L.16 SOLICITATION PROVISIONS INCORPORATED BY REFERENCE (52.252-1) (FEB 1998)

This solicitation incorporates one or more solicitation provisions by reference, with the same force and effect as if they were given in full text. Upon request, the Contracting Officer will make their full text available. The offeror is cautioned that the listed provisions may include blocks that must be completed by the offeror and submitted with its quotation or offer. In lieu of submitting the full text of those provisions, the offeror may identify the provision by paragraph identifier and provide the appropriate information with its quotation or offer. Also, the full text of a solicitation provision may be accessed electronically at this/these address(es):

Federal Acquisition Regulation (FAR) provisions:

http://www.arnet.gov/far/

NASA FAR Supplement (NFS) provisions:

http://www.hq.nasa.gov/office/procurement/regs/nfstoc.htm

(End of provision)

SECTION M OF NNK12427240R

EVALUATION FACTORS FOR AWARD

M.1 EVALUATION CRITERIA

1. Source Selection

The Government will award a contract resulting from this solicitation that represents the best value to the Government, in accordance with FAR 15.101.

The Government reserves the right to establish a competitive range for negotiation based upon the technical and cost acceptability of proposals. In addition, the Government reserves the right to award without discussions.

2. Evaluation Factors and Subfactors

The evaluation factors are Technical and Management Approach, Price, and Past Performance. These factors will be used to evaluate each proposal. This Section M provides a further description for each evaluation factor, inclusive of subfactors.

3. Relative Order of Importance of Evaluation Factors

The Price Factor is less important than the combined importance of the Technical and Management Approach Factor and the Past Performance Factor. As individual Factors, the Price Factor is less important than the Technical and Management Approach Factor but more important than the Past Performance Factor.

The Technical and Management Approach Factor is divided into four Subfactors: 1) Technical Approach, 2) Key Personnel 3) Small Business Utilization and 4) Safety and Health Plan. The Technical Approach Factor is more important than Key Personnel. The Technical Approach Factor and Key Personnel factor are significantly more important than the Small Business Utilization Factor (SBU) and the Safety and Health Plan (S&HP). SBU and S&HP are approximately equal in importance.

(End of Text)

M.2 TECHNICAL AND MANAGEMENT APPROACH FACTOR

The Technical and Management Approach Proposal must be divided and presented by each Technical and Management Approach subfactor as follows:

Subfactor A--Technical Approach
Subfactor B--Key Personnel
Subfactor C--Small Business Utilization
Subfactor D-- Safety and Health Plan

SECTION M OF NNK12427240R

EVALUATION FACTORS FOR AWARD

1. TECHNICAL AND MANAGEMENT APPROACH SUBFACTORS AND DESCRIPTION OF EACH SUBFACTOR

SUBFACTOR A--TECHNICAL APPROACH

The offeror's technical approach to meeting the requirements of the Statement of Work, Specification, and Deliverable Items List and Schedule will be evaluated for overall soundness and to determine whether the offeror has a thorough understanding of all requirements. In particular, the proposed approach to meeting the critical performance characteristics as described in Subfactor A, Technical Approach proposal instructions (Section L.16(3)), will be evaluated for overall technical merit and understanding of the requirements. Note: the performance requirements contained in the listing in Subfactor A, Section L.16(3) will not be separately point-scored, and the order of appearance implies no priority or weighting of importance in the evaluation of this Subfactor. The offeror's compliance matrix will be evaluated on the offeror's ability to meet all of the requirements from the SOW and Specification.

The offeror's ability to meet the performance and testing requirements will be evaluated to determine whether the offeror is capable of adequately designing, fabricating, and testing the hardware over the environmental constraints of the mission.

The demonstrated flight heritage for the instrument design will be evaluated for thoroughness and reliability. In addition, the offeror's reliability assessment of the design will be evaluated for reasonableness of performance and operability.

The offeror's time-phased activity and milestone schedule will be evaluated for thoroughness and completeness in identifying the duration of each task, and reasonableness in order to meet the critical elements of the required contract delivery schedule.

The offeror's identification of risks and proposed approach to the mitigation of those risks will be evaluated as appropriate. Areas of possible risk to be evaluated are technical, schedule, cost, safety, new technology, occupational health, security (including personnel, information technology, sensitive information disclosure), export control and environmental risks.

The offeror's description of non-standard practices and recommended deviations from those practices specified in the SOW will be evaluated for adequacy. In addition, the offeror's description, explanation and rationale of differences between the offeror's standards and standards specified in the SOW will be evaluated for completeness, thoroughness and reasonableness.

EVALUATION FACTORS FOR AWARD

The Quality Assurance Plan will be evaluated to determine if the offeror is continually evaluating its performance to ensure a quality product is delivered. In addition, the Plan will be evaluated to determine if it implements a Quality Management System that meets the intent of the requirements of American National Standards Institute (ANSI/ISO/American Society for Quality (ASQ) Q9001 (1994 or 2000 version or equivalent) .

The offeror's overall management approach will be evaluated for effectiveness, efficiency and thoroughness to determine whether the offeror adequately addresses the requirements and any potential challenges of this effort. The offeror's management approach for interfacing with and facilitating communication with the Government's personnel will also be evaluated for adequacy.

The offeror's proposed facility for the instrument fabrication will be evaluated for adequate capability of fabricating of highly sensitive instrumentation.

<u>SUBFACTOR B--KEY PERSONNEL</u>

The Government will evaluate the offeror's approach to project management including managing the proposed organization, including internal and external lines of authority, and relationships with Government, other contractors, and subcontractors.

The Government will evaluate the mix of proposed personnel relative to technical support requirements. The Government will evaluate the offeror's proposed key personnel, their qualifications to fill those positions.

The Government will evaluate the offeror's approach to accomplishing administrative functions.

The Government will evaluate the offeror's response capability and flexibility in assignment of personnel with required skills and allocation of resources in order to respond to sudden, unanticipated changes in tasking or priority.

The Government will evaluate the offeror's approach to temporary or permanent replace of key personnel.

<u>SUBFACTOR C--SMALL BUSINESS UTILIZATION</u>

The evaluation of Small Business Subcontracting and Commitment to the Small Business Program applies to all Offerors, except that Small Businesses are not required to submit a Small Business Subcontracting Plan.

SECTION M OF NNK12427240R

EVALUATION FACTORS FOR AWARD

(a) Small Business Subcontracting

(1) The Small Business Subcontracting Plan will be evaluated in terms of the Offeror's proposed subcontracting goals (overall subcontracting goals and individual subcontracting goals by small business category) in comparison to the Contracting Officers assessment of the appropriate subcontracting goals for this procurement. The Offeror's Small Business Subcontracting Plan will also be evaluated in terms of meeting the requirements of FAR 19.704, Subcontracting Plan Requirements. The evaluation of the Small Business Subcontracting Plan will be on the basis of total contract value.

(2) Small businesses are not required to submit subcontracting plans. NASA will only evaluate the amount of work proposed to be performed by the small business prime and any small business at the first tier subcontract level. The proposed amount of work to be done by the prime small business and first tier small business subcontractors will be evaluated against the Contracting Officer's assessment of the overall subcontracting goal for this procurement. Individual subcontracting goals by small business categories will not be evaluated for small business primes and their first tier subcontractors.

(b) Commitment to Small Businesses

(1) NASA will evaluate the extent to which any work performed by a small business subcontractor(s) is identified as "high technology." NASA also will evaluate the extent of commitment to use the subcontractor(s) (enforceable vs. non-enforceable commitments.)

(2) NASA will evaluate the extent to which the identity of the small business subcontractor is specified in the proposal as well as the extent of the commitment to use small businesses. (For small business Offerors, NASA will evaluate this only if subcontracting opportunities exist.)

(3) NASA will evaluate the Offeror's established or planned procedures and organizational structure for small business outreach, assistance, participation in the Mentor Protégé program, counseling, market research and small business identification, and relevant purchasing procedures. (For large businesses Offerors, this information should conform to its submitted Small Business Subcontracting Plan. For small business Offerors, NASA will evaluate this only if subcontracting opportunities exist.)

(End of provision)

SUBFACTOR D-- SAFETY AND HEALTH PLAN

The Government will evaluate the adequacy of the offeror's Safety and Health Plan to ensure that supplies and services are furnished in a safe and healthful manner, and that the offeror develops, produces, and/or delivers products to NASA that will be safe and successful for their intended use.

The offeror's Safety and Health Plan will be evaluated for compliance with applicable Federal and State statutory and regulatory requirements, as well as compliance with NPR 8715.3, NFS 1852.223-73 and applicable NASA Agency-wide and Installation specific policies and/or procedures including the adequacy of protection of life, health, and well being of NASA and Contractor employees, property and equipment. Further, the Safety and Health Plan will be evaluated to determine the adequacy of protection for subcontractor employees for any proposed subcontract.

2. EVALUATION FINDINGS

The Government will evaluate proposals by classifying findings as strengths, weaknesses, significant strengths, significant weaknesses, or deficiencies using the following:

Weakness – a flaw in the proposal that increases the risk of unsuccessful contract performance.

Significant Weakness – a proposal flaw that appreciably increases the risk of unsuccessful contract performance.

Deficiency – a material failure of a proposal to meet a Government requirement or a combination of significant weaknesses in a proposal that increases the risk of unsuccessful contract performance to an unacceptable level.

Strength (not in FAR/NFS) – a proposal area that enhances the potential for successful performance or contributes toward exceeding the contract requirements in a manner that provides additional value to the government (this could be associated with a process, technical approach, materials, facilities, etc.).

Significant Strength (not in FAR/NFS) – a proposal area that greatly enhances the potential for successful performance or contributes significantly toward exceeding the contract requirements in a manner that provides additional value to the Government.

(End of provision)

M.3 BUSINESS PROPOSAL

The Business Proposal volume must be divided and presented by each subfactor as follows:

Subfactor A—Offer/Model Contract
Subfactor B—Price
Subfactor C—Past Performance

SUBFACTOR A – OFFER/MODEL CONTRACT

This subfactor will not be part of the evaluation factor; however it will be reviewed for compliance to the RFP requirements.

SUBFACTOR B – PRICE EVALUATION FACTOR

This is a firm fixed price acquisition.

A price analysis will be conducted in accordance with FAR 15.305(a)(1). Price analysis is described at FAR 15.404-1. This analysis is done to ensure that a "fair and reasonable" price is paid by the Government.

EVALUATION OF OPTIONS (52.217.5) (JUL 1990)

Except when it is determined in accordance with FAR 17.206(b) not to be in the Government's best interests, the Government will evaluate offers for award purposes by adding the total price for all options to the total price for the basic requirement. Evaluation of options will not obligate the Government to exercise the option(s).

(End of Provision)

SUBFACTOR C- RELEVANT EXPERIENCE/PAST PERFORMANCE

The evaluation of past performance will be conducted in accordance with FAR 15.305(a)(2) and NFS 1815.305(a) (2). The offeror's relevant performance of work similar in size, content, and complexity to the requirements of this acquisition will be evaluated. For purposes of this Section, relevant is a contract performed within the last five (5) years that is similar in size, content, and complexity to requirements of this RFP. The Government may supplement the information contained in the proposal with information obtained from other Government organizations and personnel, commercial sources, public information sources, and, if applicable, data gathered during the discussion phase of the evaluation. Emphasis will be given to the extent of recent direct experience and quality of past performance on previous contracts that are highly relevant to the effort defined in this RFP.

This factor is not numerically weighted or scored. In accordance with NFS 1815.305, Past Performance shall be evaluated for each offeror using the following levels of confidence ratings:

Very High Level of Confidence	The Offeror's relevant past performance is of exceptional merit and is very highly pertinent to this acquisition; indicating exemplary performance in a timely, efficient, and economical manner; very minor (if any) problems with no adverse effect on overall performance. Based on the Offeror's performance record, there is a very high level of confidence that the Offeror will successfully perform the required effort. ** (One or more significant strengths exist. No significant weaknesses exist.)
High Level of Confidence	The Offeror's relevant past performance is highly pertinent to this acquisition; demonstrating very effective performance that would be fully responsive to contract requirements with contract requirements accomplished in a timely, efficient, and economical manner for the most part with only minor problems with little identifiable effect on overall performance. Based on the Offeror's performance record, there is a high level of confidence that the Offeror will successfully perform the required effort. ** (One or more significant strengths exist. Strengths outbalance any weakness.)
Moderate Level of Confidence	The Offeror's relevant past performance is pertinent to this acquisition, and it demonstrates effective performance; fully responsive to contract requirements; reportable problems, but with little identifiable effect on overall performance. Based on the Offeror's performance record, there is a moderate level of confidence that the Offeror will successfully perform the required effort. ** (There may be strengths or weaknesses, or both.)
Low Level of Confidence	The Offeror's relevant past performance is at least somewhat pertinent to this acquisition, and it meets or slightly exceeds minimum acceptable standards; adequate results; reportable problems with identifiable, but not substantial, effects on overall performance. Based on the Offeror's performance record, there is a low level of confidence that the Offeror will successfully perform the required effort. Changes to the Offeror's existing processes may be necessary in order to achieve contract requirements. ** (One or more weaknesses exist. Weaknesses outbalance strengths.)
Very Low Level of Confidence	The Offeror's relevant past performance does not meet minimum acceptable standards in one or more areas; remedial action required in one or more areas; problems in one or more areas which, adversely affect overall performance. Based on the Offeror's performance record, there is a very low level of confidence that the Offeror will successfully perform the required effort. ** (One or more deficiencies or significant weaknesses exist.)
Neutral	In the case of an Offeror without a record of relevant past performance or for whom information on past performance is not available, the Offeror may not be evaluated favorably or unfavorably on past performance [see FAR 15.305(a) (2) (ii) and (iv)].

** (At the Installations' discretion strengths and weaknesses may be assigned.)

M.4 OFFER/NO OFFER RESPONSE SHEET

Compliance is requested, but not required.

This page may be used to indicate whether your company intends to submit an offer in response to this solicitation. You may also indicate your intent by E-Mail or FAX. The E-Mail address is Chelsea.Poling@Nasa.gov The FAX number is (321)867-2825. If mailed, return the completed page to the individual and address on the face page of this solicitation.

The ____(name of firm) (/ / intends) (/ / does not intend) to submit an offer in response to **RFP- NNK12427490R**

(End of provision)

NNK12427240R -- ATTACHMENT A

STATEMENT OF WORK
FOR THE
VACUUM DEVELOPMENT UNIT (VDU) GAS CHROMATOGRAPH-MASS SPECTROMETER (GC-MS) FOR THE LUNAR ADVANCED VOLATILE ANALYSIS (LAVA) SUBSYSTEM

FEBRUARY 29, 2012

Table of Contents

1.0 INTRODUCTION

1.1 GENERAL INFORMATION

The Regolith and Environment Science and Oxygen and Lunar Volatile Extraction RESOLVE mission is to develop a payload to analyze the distribution of volatiles on the lunar surface and demonstrate in situ resource utilization. The RESOLVE project includes the development of a volatile detection instrument designed for hydrogen, water, and other relatively low molecular weight volatiles (e.g., CO, CO2, He, N2, CH4, H2S). The RESOLVE project will use a drill to obtain a sample of lunar regolith, transfer the sample to a reactor, heat the sample and analyze the volatiles with the LAVA subsystem. The LAVA subsystem will transfer the volatiles from the reactor to the GC-MS instrument for analysis and provide a water droplet demonstration. The RESOLVE project will also demonstrate oxygen extraction from lunar regolith via hydrogen reduction.

This document defines the work to be performed by the Contractor in the design, development, fabrication, and delivery of the Vacuum Development Unit (VDU) Gas Chromatograph-Mass Spectrometer (GC-MS), which shall herein be defined as VDU GC-MS. The VDU GC-MS is required to analyze the volatiles released from the lunar regolith or a representative sample during thermal vacuum testing.

In the first phase of this project the Contractor shall design the VDU GC-MS. This design shall address the requirements and goals of the technical specifications (Technical Specifications for the Vacuum Development Unit (VDU) Gas Chromatograph-Mass Spectrometer (GC-MS) for the Lunar Advanced Volatile Analysis (LAVA) Subsystem). The VDU GC-MS design will serve as the protoflight development effort. Components should be spaceflight-rated components where required or have a path to flight (drop in replacement part) based on the Class D mission classification as described in NPR 8705.4 (http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8705&s=4). The governing document for the RESOLVE VDU will be Ames Procedural Requirements for Class D Spacecraft Design and Environmental Test (APR 8070.2). The design will address the requirements with verification being done through analysis and possibly some testing or evaluation of components or subassemblies. The vendor will work with NASA to define the specific interfaces that will allow the system to be integrated into the RESOLVE LAVA subsystem.

The contractor shall perform the design review cycle consisting of a 30% design review (PDR), a continuation review at the end of FY12 (FY 12 is defined as October 1st 2011 - September 31st, 2012), and a 90% design review (CDR) tailored for this instrument.

The entrance and exit criteria of the PDR and CDR technical design review process can be found in NPR 7123.1A. The contractor shall deliver the final design package at the conclusion of this phase of the project. This shall include the deliverables listed in Section 2.4

Upon successful completion of the instrument design, the option exists for NASA to go forward with the fabrication of the instrument according to the design documentation. The contractor shall conduct testing of the system as a stand-alone instrument with initial checkout in a vacuum chamber. Because certain requirements should be tested during the buildup of the system, the contractor shall coordinate validation and verification tests with NASA and conducted throughout the project. The contractor shall perform an acceptance test to determine that the hardware meets the performance requirements. After delivery, NASA will integrate the VDU GC-MS into the RESOLVE LAVA subsystem for integrated system operation.

The GC-MS instrument shall be designed for use in a vacuum chamber and will be integrated by NASA into the RESOLVE Lunar Advanced Volatile Analysis (LAVA) Subsystem. The RESOLVE project will integrate the LAVA subsystem which will include the vacuum development unit/protoflight gas chromatograph – mass spectrometer into the overall system for thermal vacuum testing. The GC-MS product will be required to analyze the volatiles in order to identify and quantify the volatiles available from the sample.

1.2 SCOPE

The contractor shall provide the facilities, personnel, services, tools, equipment, and materials necessary to design, analyze, manufacture, test, and deliver the hardware and data in accordance with the requirements of this SOW and the documents referenced herein.

This SOW defines the contractor tasks, deliverables, responsibilities, and schedule, either within this document or by reference.

1.3 APPLICABLE DOCUMENTS

All applicable and reference documentation identified in this document shall apply in the situations where they are specifically referenced. In the event of a conflict between the SOW and the specification, the SOW shall take precedence.

2.0 MANAGEMENT, REPORTING, REVIEWS, AND DOCUMENTATION

2.1 PROGRAM MANAGEMENT

The contractor shall designate and identify by name a single individual who shall serve as a point of contact with the NASA/KSC Contracting Officer's Technical Representative (COTR) for all technical aspects of the VDU GC-MS contract.

The contractor shall manage all resources, control schedules, manage all engineering, manufacturing and procurement activities, configuration management, Quality Assurance, documentation control, and distribution.

The contractor shall propose and maintain a project schedule for the entire period of performance of the contract to include tasks, milestones, and critical paths in the project. Deviations to the project schedule shall be reported in the weekly teleconferences and monthly status reports.

2.2 REPORTING

2.2.1 WEEKLY TELECONFERENCE

The Contractor shall prepare and present to KSC a status report by weekly teleconference throughout the period of performance. This shall include, but shall not be limited to a review of the previous week's: accomplishments and progress against the original schedule; procurements; key personnel changes; completed designs, drawings, and documents; material and process changes; test and inspection results; performance assurance issues; requirements verification changes; hardware shipments; action or open items; problems; and the next week's planned activities.

2.2.2 MONTHLY STATUS REPORT

The Contractor shall prepare and submit to KSC a written Monthly Status Report to electronic mail addresses, supplied at contract award, in a PDF format file throughout the period of performance. The report shall include the same information reported in the weekly teleconferences but for the previous month. In addition the report, the contractor shall include the next month's planned activities, and updates to the schedule or a statement that the Contractor is on the last schedule submitted.

The Contractor shall provide, as part of the monthly report, a list of all open anomaly and failure reports and a list of the anomaly and failure reports closed during the month. For each reported anomaly, nonconformance and failure, there shall be a report that documents the investigation and engineering analysis needed to determine the cause and corrective actions to disposition the nonconformance.

The Contractor shall provide, as part of the monthly report, a list of the open risks and all new risks identified. The report shall include the mitigation strategies for each risk.

2.3 ADVANCE NOTIFICATIONS

The contractor shall notify the NASA/KSC COTR at least seven (7) calendar days in advance of all mandatory hardware inspections, test activities, TIM's, and deliveries at either the contractor's or a sub-contractor's facility to allow timely participation by the NASA/KSC Quality Assurance representative. Event specific notification requirements (such as failures, anomalies, etc.) are included in the appropriate sections.

2.4 DESIGN REVIEW PHASE

2.4.1 PRELIMINARY DESIGN REVIEW (PDR)

The contractor shall organize and conduct a Preliminary Design Review (PDR) at the contractor's facility, at KSC, or via teleconference at KSC's discretion by a date specified in the contract. The contractor shall provide to KSC a Preliminary Design Review Presentation Package and all other required deliverable data seven (7) calendar days prior to the review. The Preliminary Design Review shall address all program management, design, drawings, analysis, manufacturing, test, and quality assurance activities outlined in this Statement of Work document.

2.4.1.1 PDR REPORT

The contractor shall provide a Preliminary Design Review Report following the review. The report shall include the meeting notice, agenda, review meeting minutes, and responses to all recommendations and action items. The review minutes shall include attendance, action items, action item accomplishment responsibility and agreements.

2.4.1.2 PDR PRESENTATION PACKAGE

At a minimum, the design package should cover the following areas:

Design review documentation for 30% Design Review/PDR to include:

(a) Preferred system solutions including major tradeoffs and options
(b) Preliminary functional baseline with trade off analysis
(c) Preliminary system software functional requirements
(d) Preliminary risk assessment/mitigation plan and safety analysis
(e) Preliminary test plan for validation and verification of all technical requirements (Section 3.2) for the VDU GC-MS
(f) Preliminary interface control document
(g) Updated project schedule data
(h) Preliminary limited life items list to include mean time between failure values
(i) Preliminary subsystem design specifications for hardware and software
(j) Preliminary mass and power estimates to include basis of estimation (includes a comparison of estimates to requirements and plan to control growth and meet requirements and design matures)
(k) Preliminary technical plan for high and low level water detection, testing, and optimization of system for water analysis
(l) Preliminary technical plan for volatile components specified in the Technical Specification (Section 3.2) for the VDU GC-MS.

Review minutes shall be prepared and, as a minimum, shall include attendance, action items, action item accomplishment responsibility and agreements.

KSC shall not close the PDR until all open action items have been closed and approved to its satisfaction.

2.4.2 CONTINUATION REVIEW (CR)

The contractor shall organize and conduct a Continuation Review (CDR) at the contractor's facility or via teleconference at KSC's discretion by a date specified in the contract. The contractor shall provide to KSC a Review Package and all other required deliverable data seven (7) calendar days prior to the review. The Continuation Review shall address all program management, design, drawings, analysis, manufacturing, test, and quality assurance activities outlined in this SOW.

The contractor shall provide a Continuation Review Package that shall include the following items:

(a) Updated documentation from 30% Design Review/PDR (1a – l). Documents shall be presented for approval and baselined.
(b) Validation and verification plan (1e) to address all requirements in design phase of project, designating the method of verification (test, analysis, design)
(c) Testing data to support design choices and trade-offs
(d) Operational concept detailed to support analysis modes defined in the Technical Specification (Section 3.2) for the VDU GC-MS.
(e) Preliminary user interface description
(f) Demonstrated GC-MS sampling rate to obtain a full mass spectrum for 0.8 Th to 68 Th at greater than or equal to 6 Hz

The contractor shall provide Continuation Review Report following the review. The report shall include the meeting notice, agenda, review meeting minutes, and responses to all recommendations and action items. The review minutes shall include attendance, action items, action item accomplishment responsibility and agreements.

2.4.3 CRITICAL DESIGN REVIEW (CDR)

The contractor shall organize and conduct a Critical Design Review (CDR) at the contractor's facility, at KSC, or via teleconference at KSC's discretion by a date specified in the contract. This presentation shall demonstrate overall conformance of the requirements specified in the VDU GC-MS technical specification, and this Statement of Work for this phase of the procurement. This presentation shall cover programmatic, technical, test and verification, and quality assurance topics, and address any changes made to the documentation since PDR. This review shall provide an opportunity to review the design, test and analysis of the proposed VDU GC-MS instrument design.

2.4.3.1 CDR REPORT

The Contractor shall provide a Critical Design Review Report following the review in accordance with the “VDU GC-MS Deliverable Items List and Schedule,” The report shall include the meeting notice, agenda, review meeting minutes, and responses to all recommendations and action items. The review minutes shall include attendance, action items, action item accomplishment responsibility and agreements.

2.4.3.2 CDR PRESENTATION PACKAGE

The contractor shall provide a CDR Presentation Package. This shall address the performance and design specifications in the technical specification document. The design package shall include the following:

90% Design Review/CDR

(a) Updated functional baseline with trade-off analysis
(b) Updated system software functional requirements
(c) Updated risk assessment/mitigation plan and safety analysis
(d) Updated test plan for validation and verification of all requirements listed in Section 3.2 of the Technical Specifications VDU GC-MS
(e) Updated interface control document
(f) Updated schedule data
(g) Updated limited life items list
(h) Updated subsystem design specifications for hardware and software
(i) Updated mass and power estimates to include the basis of estimation
(j) Updated technical plan for high-level and low-level water detection, testing, and optimization of the system for water vapor analysis
(k) Updated technical plan for detection of volatile components specified in the technical specifications (Section 3.2)
(l) Demonstration of water detection range and reproducibility on a GC system representative of the contractor’s technical approach, including all materials planned for use in the system from injection to detection. Generation of known water concentrations should use a laboratory standard generator or standard salt bath solutions.
(m) Demonstration of permanent gas separations, including hydrogen/helium separation and thermal conductivity detector (TCD) detection limits for all vapors
(n) Test/analysis/design data to support validation and verification of all requirements defined in the Technical Specifications (Section 3.2) for the VDU GC-MS
(o) Software DDS Interface Definition Language Documentation
(p) Preliminary programmers guide to DDS interface
(q) Report on main-board computer that will be used to run DDS interface

(r) Electrical drawings, schematics, and connector pinouts
(s) Validation and verification plan for hardware checkout
(t) Updated project cost estimates for deliverables in Fabrication Phase
(u) Mechanical drawings, CREO/Pro-E Wildfire 5 compatible drawings of 90% of the system, including components and the integrated instrument
(v) A preliminary Bill of Materials of all components specified in the design of the system. As a minimum, the Bill of Materials shall provide the item description, manufacturer's part number, lead time for procurement, supplier, supplier's part number, and component designator (if applicable).

Final report to include design choices, justification for design choices, data collected during testing/evaluation of components, and options considered during the design phase.

KSC shall not close the CDR until all open action items have been closed and approved to its satisfaction.

2.4.4 DESIGN PHASE PROJECT SCHEDULE

The contractor shall supply an updated project schedule that shall include milestone charts depicting critical paths and indicating critical dates in the program in accordance with the "VDU GC-MS Deliverable Items List and Schedule". The Contractor shall define the start, implementation, and completion dates for the detailed activities associated with the design, analysis, manufacturing, and testing of all components, subassemblies, and integrated system. The Contractor shall identify the vendor lead times for procured parts and materials specified in the design.

2.5 FABRICATION PHASE

The contractor shall fabricate all components required to assemble, integrate, and test the VDU GC-MS instrument(s) to support the delivery dates as called for in the contract.

2.5.1 DATA DELIVERY PACKAGE

The contractor shall prepare and deliver a data delivery package to the KSC with the VDU instrument(s) in accordance with the "VDU Deliverable Items List and Schedule," For each instrument, this report shall contain the as built configuration list, a list of parts and materials used in the instrument, a list of processes used to manufacture the instrument, a test log book for each test which documents the total operating time and cycles for each test, a list of open items and the reason the items are open, results of the verifications required by this specification including dates of completion and what test equipment was used, TQCM data, a summary of all repairs for that instrument, a series of digital color photographs that capture all relevant views of the instrument, and a copy of all problem/failure reports generated against the instrument. The Contractor shall document the issue numbers of the drawings and specifications to which particular hardware has been fabricated, inspected, and tested as the as-built configuration.

The Contractor shall provide evidence of compliance with the as-built documentation as a basis for acceptance of the hardware.

(a) Full drawing package of "as-built" system, to include a full drawing package of electronics, drawing package of mechanical components, owner's manuals for OEM items, parts list for all components including part number, manufacturer information, and data sheets.

(b) A final Bill of Materials of all components used to fabricate the system. As a minimum, the Bill of Materials shall provide the item description, manufacturer's part number, lead time for procurement, supplier, supplier's part number, and component designator (if applicable).

(c) Test plans and data taken during build and checkout of the system to include GC chromatograms and MS scans of sample mixtures to demonstrate the system's ability to meet requirements.

(d) Safety documentation. The contractor shall perform any safety related analyses necessary to support the safety requirements of Section 4.2. The results of these analyses shall be summarized in a Contractor format Safety Analysis Report that will be provided to the NASA/KSC COTR for review.

(e) Operator's manual, to include instructions for warm-up, calibration, operation, troubleshooting, shutdown and shipping instructions.

(f) Maintenance manual, to include instructions for replacement of components with an operational limited lifetime (less than 2 years).

(g) Long lead items list to include estimated lead time and vendor quotes for components with an estimated lead time over 3 months.

2.5.2 GENERAL REQUIREMENTS

The contractor shall provide a Fabrication, Assembly, and Inspection Flow plan in accordance with the VDU GC-MS Deliverable Items List and Schedule that shall include a step-by-step procedure that describes the method of fabrication, assembly, and inspection from piece parts to the completely assembled VDU GC-MS instrument.

The contractor shall provide the following hardware to meet the requirements of the technical specification

One functional GC-MS systems built to design specifications with an option to procure up to two additional units.

2.6 TECHNICAL INTERCHANGE MEETINGS (TIM)

The contractor shall plan for and facilitate up to five (5) informal, face-to-face technical interchange meetings to be held at the contractor and/or NASA facilities. These TIMs shall support review and coordination of technical issues including, but not limited to, parts, test plans, test procedures, software changes, design modifications, and design analyses.

2.7 DOCUMENTATION

The contractor shall ensure the generation and delivery of all documentation as called for in the contract and listed in deliverable items list.

In addition to that documentation specifically called for in the contract, upon request by the NASA/KSC COTR, the contractor shall make available a copy of any document or data generated during this contract performance for review by KSC at either the contractor's facility or via the internet. This includes, but is not limited to, technical reports and memorandums, drawings, schematics, studies, analyses, parts and materials data, test data, alerts, etc.

2.8 DRAWING PACKAGE

The contractor shall supply a drawing package for the GC-MS instrument.

The contractor shall provide a drawing package that includes, but is not limited to:

ELECTRICAL:	assembly and electrical interface drawings (board level schematics available on request)
INTERFACE:	interface drawings (to include but not limited to thermal and mechanical

2.9 MECHANICAL MODELS: ASSEMBLY AND INTERFACE DRAWINGS COMPUTER MODELS

The contractor shall deliver the models used in the design analysis and performance of the below analyses or used for CAD/CAM/CAE in a file format compatible with CREO/Pro-E Wildfire 5

Drawing package required by Section 3.2 of this SOW must be in a format that is compatible with CREO/Pro-E Wildfire 5.

2.10 INTERFACE CONTROL DOCUMENT (ICD)

The contractor shall generate and deliver an Interface Control Document. This document shall specify all interfaces of the instrument to include but not limited to electrical, mechanical, thermal and software/communication. This document shall be a contractor controlled document and shall indicate all changes made after the initial approval by KSC. After ICD approval, no changes shall be made without written NASA/KSC CO and COTR approval.

2.11 COMMUNICATION AND CONTROL SPECIFICATION DOCUMENT (CCSD)

The contractor shall generate and deliver Communication and Control Specification Document (CCSD). This plan shall be a contractor controlled document and shall indicate all changes made after the initial approval by the KSC. After Communication and Control Specification Document approval, no changes shall be made without written NASA/KSC CO and COTR approval.

The CCSD shall specify the external interface for command and data and state transfer using Object Management Group (OMG)-compliant Data-Distribution Service (DDS) for Real-Time Systems middleware. The DDS shall be compatible with Twin Oaks CoreDX DDS. Externally initiated commands shall use a DDS Quality of Service (QOS) of "Reliable" while data and state information published to DDS shall use a QOS of "Best Effort."

The CCSD shall specify the protocol/commands that the GC-MS employs to subscribe to DDS commands and publish state and data via DDS as defined in valid interface definition language (IDL) files, which shall be provided electronically no later than upon the delivery of the instrument.

This document shall include the source code and software environment that is used in the testing of the GC-MS system as an appendix. The source code on the GC-MS instrument and the user interface shall be delivered in digital format.

The CCSD shall provide the firmware, field programmable gate array (FPGA) or application specific integrated circuit (ASIC) source code, such as, VHDL employed in the GC-MS instrument. The CCSD shall include digitally formatted files for reprogramming of spares.

2.12 STRUCTURAL ANALYSIS REPORT

The purpose of the structural analyses is to demonstrate compliance with the mechanical/structural design and test requirements. Structural analyses verify the structural integrity of the hardware by assessing the size and location of applied loads, load paths, and critical failure modes. A Structural Analysis shall be performed on the Vacuum Development Unit GC-MS structure to ensure the capability to withstand and survive launch, ascent, and on-orbit loads. Beryllium and composite materials shall not be qualified by analysis alone. The effects of any thermal inputs shall be reflected in the analyses as appropriate. This analysis shall include a Venting analyses for applicable components susceptible to pressure loadings to verify that positive strength margins exist at loads equal to twice those induced by the maximum pressure differential during launch. The results of these analyses shall be summarized in a contractor format Structural Analyses Report that will be provided to the NASA/KSC COTR for review.

2.13 FABRICATION PHASE PROJECT SCHEDULE

The contractor shall supply an updated project schedule on a monthly basis during the fabrication phase that shall include milestone charts depicting critical paths and indicating critical dates in the program in accordance with the "VDU Deliverable Items List and Schedule,". The Contractor shall define the start, implementation, and completion dates for the detailed activities associated with the design, analysis, manufacturing, and testing of all components, subassemblies, and integrated system Hardware Procurement/Manufacturing

2.14 REPAIR PARTS

The contractor shall supply parts sufficient to repair limited life items to include high voltage power supplies, ionization sources, gas columns, detectors, and wire. The contractor shall supply these parts in the quantities required in the DIILS.

The contractor shall supply up to 1,000 centimeters of each type wire it has used in fabricating the GC-MS.

The contractor shall supply a minimum of 2 spare mass spectrometer detectors for each GC-MS instrument.

The contractor shall supply a minimum of 2 spare thermal conductivity detectors for each GC-MS instrument.

The contractor shall supply a minimum of 2 spare ionization sources for each source installed in the GC-MS instrument.

The contractor shall supply 1 each of a spare gas chromatography column for each gas column specified in the GC-MS instrument

The contractor shall supply one complete spare set of connectors, pins, and sockets.

The contractor shall supply one spare high voltage power supply

With the exception of adhesives, the contractor shall supply other parts it deems necessary to repair the GC-MS.

2.15 GOVERNMENT INDUSTRY DATA EXCHANGE PROGRAM (GIDEP)

The contractor shall participate in the GIDEP consistent with NPR 8735.1 Procedures for Exchanging Parts, Materials, and Safety Problem Data Utilizing Government-Industry Data Exchange Program and NASA Advisories. The contractor shall participate in the GIDEP in accordance with the following:

- GIDEP S0300-BT-PRO-010 GIDEP Operations Manual
- S0300-BU-GYD-010 Government-Industry Data Exchange Program (GIDEP) Requirements Guide

3.0 PERFORMANCE VERIFICATION AND TEST

3.1 VERIFICATION REQUIREMENTS

The contractor shall verify all requirements specified in the RESOLVE LAVA GC-MS Technical Specifications Document.

The contractor shall provide a verification matrix defining the method of verification for each specific requirement of the RESOLVE LAVA GC-MS Technical Specifications Document.

In-process production evaluation tests and environmental stress screening tests shall also be considered to be verification tests.

3.2 VERIFICATION PLAN

A Verification Plan shall be generated by the contractor to describe the details of how the analyses, inspections, and verification tests identified in the VDU GC-MS Technical Specification will be performed. Verification tests shall demonstrate the item meets all of the specified performance requirements over the specified range of environments, measure performance parameters and reveal inadequacies in manufacturing and assembly such as workmanship or material problems. Any requirement that exceeds previous qualification test data shall be presented to the RESOLVE project as part of the planning process for evaluation and a possible delta qualification test.

The plan should state the purpose of each test, state acceptance criteria, describe in detail the test method, set up, instrumentation, data analysis methods (if applicable), and give the sequence of the tests. The plan should include a verification matrix summarizing how all requirements are verified (analysis, inspection, test, per the definitions in the Spec.), and listing all tests that will be performed on the GC-MS instrument(s).

This plan shall be a contractor controlled document and shall indicate all changes made after the initial approval by the KSC. After Verification Plan approval, no changes shall be made without written NASA/KSC CO and COTR approval.

If any individual test plans are created in addition to the Verification Plans described below, such as for Thermal Vacuum testing, those plans shall also be provided.

3.3 VERIFICATION TEST PROCEDURES

The contractor shall generate Verification Test Procedures for the verification tests required by this document and by the LAVA GC-MS Verification Plan and LAVA GC-MS Technical Specification Document. The verification procedures shall be step-by-step instructions for performing tests outlined by the Verification Test Plan. The procedures shall define the environmental conditions for the tests, required equipment and facilities, test constraints, software environment and source code of diagnostic or performance test software, operating conditions, tolerance on all input stimuli, data to be recorded and pass/fail limits.

Verification Test Procedures shall be contractor controlled documents and shall indicate all changes made after the initial release for review to NASA. If a Thermal Vacuum Test Procedure is created, it should include Chamber Configuration.
The contractor shall deliver the GC-MS Test Procedure in accordance with the DIILS.

3.4 ANALYSIS, TRENDING, AND REPORTING OF TEST DATA

The contractor shall record, maintain and analyze test information during the normal test program to assess performance and to aid in the identification and analysis of hardware failures and problems.

3.5 VERIFICATION TEST REPORTS

The contractor shall generate Verification Test Reports. These reports shall document the results of the each test that was performed, what test levels were achieved, what performance requirements were verified, what anomalies were seen, and how they were resolved. The contractor shall generate a Test Report for each test performed in the Verification Plan to address the Technical Specification Document.

The contractor shall deliver the following test reports in accordance with the Deliverable Item List and Schedule.

3.6 FINAL MEETING/PRESENTATION

The contractor shall support a final presentation no later than 30 days after the hardware is delivered to KSC. This presentation will cover the deliverables provided at the time of hardware delivery. An agenda shall be provided to the KSC/CO and KSC/COTR a minimum of 14 days before the presentation for review and acceptance. The presentation shall be delivered at the time of the meeting in electronic format.

4.0 QUALITY ASSURANCE

4.1 GENERAL REQUIREMENTS

4.1.1 QUALITY ASSURANCE PLAN/MANUAL

The contractor shall have a Quality Management System that is compliant with the requirements SAE AS9100 Quality Systems - Aerospace - Model for Quality Assurance in Design, Development, Production, Installation and Servicing or equivalent, as documented in a Quality Assurance Plan. The Plan shall be delivered to NASA/KSC, and the COTR shall be notified of any changes to the QA program.

4.1.2 RELIABILITY

The contractor shall manage reliability to show that the design reliability is consistent with mission design life requirements. This will primarily consist of the contractor performing the reliability analyses concurrently with design activities in order to optimize system configuration and identify and promptly correct potential problems.
Vendor shall provide mean time between failure (MTBF) of major components (pumps, heaters, valves, etc) and subassemblies (PCB assemblies, mass analyzer subassembly (including possible RF power supplies, high voltage power supplies, etc) to support analysis of design to meet reliability requirements.

4.1.3 SURVEILLANCE OF THE CONTRACTOR

The work activities and operations of the contractor, subcontractors, and suppliers are subject to evaluation, review, survey, and inspection by KSC representative.

The contractor shall provide the KSC representative with documents, records, equipment, and workings areas within their facilities that are required by the representative to perform their overview activities.

4.1.4 GOVERNMENT SOURCE INSPECTION

The Government may elect to perform inspections at a supplier's facilities. The following statement shall be included on all procurement documents: “All work on this order is subject to inspection and test by the Government in accordance with the inspection clauses in the contract.”

The Government quality representative who has been delegated NASA quality assurance functions on this procurement shall be notified immediately upon contractor receipt of any supplier/subcontractor orders. The Government representative shall also be notified 48 hours in advance of the time that articles or materials are ready for inspection or test.

4.1.5 CONFIGURATION MANAGEMENT

The contractor’s Configuration Management (CM) system (available for review on request) shall control the design and hardware/software by means of drawings, specifications, and other documents and shall ensure all applicable changes are reviewed in a systematic manner to determine the validity and impact on performance and schedule. The contractor’s Configuration Management system shall have a change classification and impact assessment process that ensures Class I changes are forwarded to the CO for approval prior to release/incorporation. Class I changes are defined as changes that affect form, fit, function, external interfaces, or requirements as stated within this document and the VDU GC-MS technical specification.

All other changes are considered to be Class II changes and shall be controlled and dispositioned by the contractor. All Class II changes shall be provided monthly to the NASA/KSC CO and COTR for review purposes. NASA/KSC reserves the right to review all Class II changes for technical content to ensure the proper classification has been assigned. Any item that is found to be non-compliant with the quality, workmanship and performance requirements of the contract shall be dispositioned via a waiver, unless the affected item is reworked to restore compliance or is replaced with a fully compliant item. The contractor shall submit Waivers to the NASA/KSC CO and COTR for final approval.

4.1.6 GROUND SUPPORT EQUIPMENT INTERFACES

Mechanical and electrical ground support equipment (GSE) and associated software that directly interfaces with vacuum development deliverable items shall be assembled and maintained to mitigate potential risk to hardware.

4.2 SYSTEM SAFETY REQUIREMENTS

The contractor shall supply detailed descriptions of the design, test, operation and inspection requirements for all VDU hardware and materials, ground support equipment, and their interfaces necessary for a valid identification, assessment, control and mitigation of documented hazards. This includes technical information concerning hazardous and safety critical equipment, systems, operations, handling and materials. For all identified hazards, the contractor shall also document hazard controls, verifications and tracking methods.

The contractor shall provide technical support to the RESOLVE-LAVA Project for safety working group and technical meetings as necessary.

4.2.1 LIMITED-LIFE ITEMS

The contractor shall identify and manage limited-life items. Limited-life items include all hardware that is subject to degradation because of limited shelf life or expected operating times or cycles such that their expected useful life is less than twice the required life when fabrication, test, storage, and mission operation are combined.

The use of an item whose expected life is less than twice the mission design life shall require approval of the NASA/KSC CO and COTR. For materials that have exceeded their allowable shelf life, a waiver can be submitted to the NASA/KSC CO and COTR for use.

4.3 REQUEST FOR INFORMATION/CLARIFICATION (RFIC)

A Request For Information/Clarification (RFIC) is used for contractor initiated Engineering Change Proposals (ECP) per NFS 1852.243-70 and for technical clarification of the delivery order.

The Contractor shall promptly report to the Contracting Officer all problems or conflicting technical information encountered during the contract performance so that the Government may provide solutions or appropriate direction. Such problems shall be reported on KSC Form No. 8-268 “Request for Information/Clarification,” to be provided by the Government.

A copy of each RFIC will be provided to the Contracting Officer's Technical Representative (COTR) concurrently with the transmittal to the Contracting Officer. The Contractor shall log and control each RFIC, including those generated by subcontractors. The RFIC will be returned to the Contractor with the appropriate information within 10 working days. KSC Form 21-34NS will be used to document an Engineering Order when design changes are necessary as a result of an RFIC

4.4 DEVIATIONS AND WAIVERS

Deviations and Waivers are contractor initiated ECPs per NFS 1852.243-70.

All contractor deviation and waiver requests shall be submitted on KSC Form 8-69, "Contractor Request to use Non-Conforming Parts or Material." The form shall be fully executed and include a proffer of consideration to the Government. The request must be technically supported by justification, rationale, design consideration, calculations, and other data as applicable that permits ready and conclusive evaluation by the Government. One copy of each approved deviation and waiver shall be included in the Acceptance Data Package (ADP). Accordingly, a D/W may be subject to a cost estimate. All D/Ws outside the scope of the delivery order shall be subject to approval by the NASA Contracting Officer.

When the contractor proposes to perform work that does not conform to the applicable contract drawing requirements and specifications, the contractor shall submit to the Contracting Officer, for approval, a written request for deviation or request for waiver on the non-conforming work.

Where a requested deviation or waiver on a particular work aspect affects other work aspects, the other work aspects shall be clearly identified and referenced. If the requested deviation or waiver necessitates a deviation or waiver on the other aspects, requests for all such deviations and waivers must be submitted concurrently.

4.5 TRAINING AND CERTIFICATION

The supplier is responsible for maintaining a documented training and certification program that meets all the requirements of NASA-STD-8739.4 section 5 or equivalent.

4.6 FACTORY ACCEPTANCE TESTING

The Contractor shall submit a factory acceptance test procedure for NASA engineering approval no less than thirty (30) days before the start of the test. The factory acceptance test shall be performed at the Contractor's facility prior to shipping to the Kennedy Space Center and include but is not limited to a subset of the verification test plan to be proposed by the vendor and accepted by the NASA KSC CO and COTR.

4.7 GOVERNMENT SOURCE INSPECTION (GSI)

Government Source Inspection (GSI) is required on this Purchase Order/Contract prior to invoiced product shipment. The contractor shall notify the Quality Assurance Representative (QAR) immediately upon receipt of this Purchase Order/Contract. The contractor shall notify the NASA-

Kennedy Space Center (KSC) Procurement QAR immediately upon receipt of this order. The contractor shall also notify the responsible QAR at least five (5) working days in advance of the date goods or services will be ready for tests, inspections, or other Mandatory Inspection Points (MIPs), as required and indicated in the Purchase Order/Contract. MIPs are designated by the Government. Evidence of GSI must be indicated by the QAR's stamp or signature on the contractor's shipping document. In the event the QAR cannot be contacted, notify the NASA KSC Contracting Officer immediately. All work on this Purchase Order/Contract is subject to inspection and test by the Government at any time and any place.

4.7.1 INSPECTION CONTROL POINT OUTLINE (MANDATORY INSPECTION POINTS (MIPS)

Special inspections, called MIPs, will be designated by the Government during the performance of this contract. Prior to the start of work, the contractor shall provide the NASA KSC Procurement QAR a schedule / Inspection Control Point Outline (ICPO) which shows the work sequence(s) to be employed during the performance of this Purchase Order. The contractor's schedule/ICPO must indicate what types of contractor inspections will be performed and where in the contract's sequence of events they will be accomplished. If applicable, the schedule/ICPO must also indicate the specification(s) (including revisions) and/or other documentation that will be used to perform the indicated inspections. The Government will identify which inspections/tests/work steps require Government Quality Assurance witness. These inspections/tests and/or work steps will be designated as MIPs. The contractor shall notify The NASA KSC Procurement QAR at least five (5) working days prior to the occurrence of a scheduled, designated MIP. Designation of MIPs does not relieve the contractor of the obligation to perform all contractually required inspections.

4.7.2 CERTIFICATES OF COMPLIANCE

Certificates of Compliance (COC's) shall be provided in the Acceptance Data Package (ADP). The COC's shall include material supplier's or equipment manufacturer's statement that the supplied material or equipment meets all specified requirements. Each certificate shall be signed by an official authorized to certify, in behalf of material supplier or product manufacturer and shall identify quantity and part number to which the certificates apply. Certification shall not be construed as relieving the contractor from furnishing materials and products conforming to contract requirements.

4.7.3 COMPONENT TRACEABILITY

Material certifications must be traceable to each item or component with a unique identifier (commonly referred to as A-Numbers or Find Numbers) and/or serial number. All required test results and certifications shall be packaged with each unique component. Copies of test results, certifications, and component data sheets shall be included in the final data package in accordance with KNPR 8715.3

4.7.4 ACCEPTANCE DATA PACKAGE

An Acceptance Data Package (ADP) shall be maintained through the duration of the contract and contain all correspondence between the Contractor and NASA, quality control documents, final acceptance inspection records and any other documentation required to administer the successful completion of the contract. The ADP shall be included with each shipment for the units or items shipped. A complete ADP for all units will be provided to the NASA Contract Administrator. At a minimum the package will contain the documents:

(a) Copy of Correspondence (Most Current Documentation on Top/Filed by Hardware Deliverable)
(b) As Build Drawings (redlines) including all schematics, diagrams and Engineering Orders
(c) Commercial Warranties
(d) Approved Deviations and Wavers
(e) Requests for Information/Clarification
(f) Certificates of Compliance
(g) Bill of Materials of all components
(h) Interface Control Document and Drawings
(i) DDS Interface Definition Language Documentation
(j) Communication and Control Specification Document
(k) Operators Manual
(l) Approved Acceptance Test Procedures
(m) Final Acceptance Test Records
(n) Factory acceptance test report and Records of Factory Inspection
(o) Material Certifications
(p) Subtier Contractor Identification
(q) Operator certifications for welding and soldering
(r) Quality Inspection Control Outline and Record
(s) Field Discrepancy Reports
(t) Copy of Shipping Document
(u) Commercial Warranties- Any parts with a commercial warranty provide a copy of the warranty with the ADP.

4.8 WORKMANSHIP STANDARDS AND PROCESSES

The developer's workmanship program shall fully encompass the specific requirements of this chapter. It is the contractor's responsibility to list all deviations from the baseline workmanship standards and to provide data supporting their position/rationale.

4.8.1 WORKMANSHIP REQUIREMENTS FOR DIODE BOARDS, SOLDERED ASSEMBLIES, HARNESSING, AND FIBER OPTICS

The following workmanship standards shall apply to printed circuit boards, soldered assemblies, harnessing, and fiber optics.

- Conformal Coating and Staking: NASA-STD-8739.1, Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
- Surface Mount Technology (SMT): NASA-STD-8739.2, Workmanship Standard for Surface Mount Technology
- Hand Soldering Assemblies: NASA-STD-8739.3, Soldered Electrical Connection
- Crimping, Wiring, and Harnessing: NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring
- Printed Wiring Board (PWB)Design: Space Flight PWB designs shall not include features that prevent the finished board(s) from complying with the Class 3 Requirements of the appropriate manufacturing standard (e.g., specified plating thickness, internal annular ring dimensions, etc.).
    - IPC-2221, Generic Standard on Printed Board Design
    - IPC-2222, Sectional Design Standard for Rigid Organic Printed Boards
    - IPC-2223, Sectional Design Standard for Flexible Printed Boards
    - IPC-2225 Sectional Design Standard for Organic Multichip Modules (MCM-L and MCM-L Assemblies)
- Printed Wiring Board (PWB)Manufacture:
    - IPC-A-600, Acceptability of Printed Boards (Class 3 requirements)
    - IPC-6011, Generic Performance Specification for Printed Boards (Class 3 requirements)
    - IPC-6012, Qualification and Performance Specification for Rigid Printed Boards (Class 3/A requirements)
    - IPC-6013, Qualification and Performance Specification for Flexible Printed Boards (Class 3 requirements)
    - IPC-6015 Qualification and Performance Specification for Organic Multichip Module (MCM-L) Mounting and Interconnecting Structures
    - IPC-6018 Microwave End Product Board Inspection and Test

The contractor shall provide test Printed Wiring Board (PWB) coupons to the NASA/KSC COTR, or to a KSC approved laboratory for evaluation. Printed Wiring Board (PWB)coupon approval shall be obtained from the NASA/KSC COTR or a KSC approved laboratory prior to population of VDU Printed Wiring Board (PWB). KSC will ensure that analysis is performed and a response is provided within 21 days of receipt of test.

5.0 HANDLING, STORAGE, PACKAGING, PRESERVATION, AND DELIVERY

Products shall be stored, preserved, marked, labeled, and packaged to prevent loss of marking, deterioration, contamination, excessive condensation and moisture, or damage during all phases of the program. Stored and stocked items shall be controlled in accordance with documented procedures and be subject to quality surveillance.

Contractor is responsible for providing an acceptable shipping container that protects the hardware appropriately.

While in a shipping container, the GC-MS shall be wrapped in a non-ESD-generating vapor barrier with redundant maximum humidity indicators. Packaging materials and methods shall not degrade the molecular or particulate cleanliness of the item.

The shipping container shall also include shock and humidity indicators and shall be capable of prolonged shipping conditions. The contractor shall document what action NASA KSC is to take if the sensors are tripped when hardware arrives at the NASA KSC receiving area. A copy of this document shall be included with shipping documentation.

By executing the act of product shipment, the supplier certifies that the product complies with all contract requirements. Prior to shipping, quality assurance personnel shall ensure that:

(a) Fabrication, inspection, and test operations have been completed and accepted.
(b) All products are identified and marked in accordance with requirements.
(c) The accompanying documentation (developer's shipping and property accountable form) has been reviewed for completeness, identification, and quality approvals.
(d) Evidence exists that preservation and packaging are in compliance with requirements.
(e) Packaging and marking of products, as a minimum, comply with Interstate Commerce Commission rules and regulations and are adequate to ensure safe arrival and ready identification at their destinations.
(f) The loading and transporting methods are in compliance with those designated in the shipping documents.
(g) Integrity seals are on shipping containers and externally observable shock or humidity monitors do not show excessive environmental exposure.
(h) In the event of unscheduled removal of a product from its container, the extent of re-inspection and retest shall be as authorized by NASA or its representative.
(i) Special handling instructions for receiving activities, including observation and recording requirements for shipping-environment monitors are provided where appropriate.

(j) Shipping documentation and containers shall contain appropriate measures (signs/warnings) to ensure that the item’s packaging is only removed or opened inside of a clean room or on a flow bench.

(k) Special handling instructions for receiving activities, including observation and recording requirements for shipping-environment monitors are provided where appropriate.

The contractor’s quality assurance organization shall verify prior to shipment that the above requirements have been met and shall sign off appropriate shipping documents to provide evidence of this verification. The contractor has the responsibility for any damage incurred during shipment.

APPENDIX A. LIST OF APPLICABLE DOCUMENTS

All referenced documentation identified in the SOW shall apply in the situations where they are specifically referenced.

Sections	Title	Revision/Date
Many	VDU GC-MS Specification	2/29/2012

NNK12427240R – ATTACHMENT B

TECHNICAL SPECIFICATION FOR THE VACUUM DEVELOPMENT UNIT GAS CHROMATOGRAPH-MASS SPECTROMETER

FEBRUARY 29, 2012

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TABLES

ABBREVIATIONS, ACRONYMS, AND SYMBOLS

µm	micrometer or micron
AIAA	American Institute of Aeronautics and Astronautics
amu	atomic mass unit
ANSI	American National Standard Institute
ARP	Aerospace Recommended Practice
ASTM	American Society for Testing Materials
BOL	beginning of life
C	Celsius
CDR	Critical Design Review
CH_4	methane
CLV	Crew Launch Vehicle
CO	carbon monoxide
CO_2	carbon dioxide
COPV	composite overwrapped pressure vessels
COTR	Contracting Officer Technical Representative
CVCM	collected volatile condensable materials
D	Deuterium
Da	dalton
DDS	Data Distribution Services
DOD	Department of Defense
dp/dt	delta pressure/delta time
E3	electromagnetic environmental effects
ELV	expendable launch vehicle
EMC	electromagnetic compatibility
EMI	electromagnetic interference
EOL	end of life
ESD	electrostatic discharge
FMECA	failure mode, effects, and criticality analysis
FOS	factor of safety

FSS	Fluid Sub-System
FY	fiscal year
g	gravity
GC	gas chromatograph
GEVS	General Environmental Verification Standard
GFE	Government Furnished Equipment
GSFC	Goddard Space Flight Center
H_2S	hydrogen sulfide
HDBK	handbook
H	Hydrogen
He	helium
Hz	hertz
IDL	interface definition language
IR	infraread
ISO	International Organization for Standardization
ISRU	*in situ* resource utilization
K	Kelvin
KSC	Kennedy Space Center
LCROSS	Lunar Crater Observation and Sensing Satellite
LAVA	Lunar Advanced Volatile Analysis
LOD	limit of detection
LRO	Large Radio Observatory
MAC	mass acceleration curve
Mbps	megabits per second
MIL	military
MMPDS	Metallic Materials Properties Development and Standardization
MS	mass spectrometer
msec	millisecond
MSFC	Marshall Space Flight Center
N_2	nitrogen
NIR	near infrared

NPD	NASA Procedural Document
NPR	NASA Procedural Requirements
OD	outside diameter
OEM	original equipment manufacturer
OMG	Object Management Group
Pa	pascal
Pb	lead
PCB	printed circuit board
PDR	Preliminary Design Review
POGO	Prevention of Coupled Structure Propulsion Instability
ppm	parts per million
psi	pounds per square inch
psia	pounds per square inch absolute
RESOLVE	Regolith and Environment Science and Oxygen and Lunar Volatile Extraction
SAE	Society of Automotive Engineers
SCCM	standard cubic centimeters per minute
sec	second
SPEC	specification
STD	standard
STP	standard test pressure or Standard Temperature and Pressure (273 K and 760 Torr)
TBR	to be reviewed
TCD	thermal conductivity detector
Th	Thompson
TM	torque margin
TML	total mass loss
VDC	volts direct current
VDU	Vacuum Development Unit

1. INTRODUCTION

1.1 Background

The detection and quantification of resources beyond our planet is vital for both exploration and science. Providing ground truth data for available resources will expand the exploration capabilities of National Aeronautics and Space Administration (NASA) programs as well as provide scientific insight into the origins and sources of the resources. Resources include volatile species such as hydrogen, helium, water, and carbon-based molecules. Identification of these species, water in particular, is a challenge because of the bonding characteristics of this molecule and its interaction with surfaces.

Data from remote sensing missions to the Moon such as the Clementine and Lunar Prospector missions (1994 and 1998, respectively) and the later, more surface-material-invasive Large Radio Observatory/Lunar Crater Observation and Sensing Satellite (LRO/LCROSS) missions (2009) indicated the presence of potentially significant quantities of hydrogen-bearing molecules in permanently shadowed craters near the lunar poles. These hydrogen-bearing volatiles, along with any other volatiles that are possibly co-located, would be extremely useful resources. The presence of water on the Martian surface also indicates that an important resource is available for this long-duration mission destination. The extraction and processing of space resources into useful products is known as *in situ* resource utilization (ISRU) and can have a substantial effect on individual missions and mission architecture concepts. In particular, the ability to make propellants, life support consumables, and fuel cell reagents can significantly (1) reduce mission cost by reducing launch mass, providing affordable prepositioning of consumables, and enabling hardware reusability; (2) reduce risk by providing backup life support consumables and reduced dependence on Earth; and (3) enable extended surface operations by providing an energy-rich environment and affordable access to multiple surface targets.

Despite the importance of water and the detection of other volatiles, many analytical systems suitable for permanent gases and other volatiles are very poor at water analysis. Current systems have limited capabilities for water quantification, primarily because of surface interactions of the instrument with water molecules. Sample loss and carryover are two common problems associated with water detection in today's state-of-the-art analytical systems, including mass spectroscopy and gas chromatography. Spectroscopic systems, including infrared (IR) and near infrared (NIR) cannot analyze diatomic or inert gases, and our needs include analysis of hydrogen, helium, and nitrogen.

The development of an instrument that detects volatiles in the low mass range (between 0.8 Th and 68 Th) and that includes a careful design for water analysis would benefit numerous exploration missions that entail resource identification. In addition to the insight that this data will provide into the available resources on other celestial bodies, it will also give information on the origins and history of those bodies.

Instruments that have been used for volatile detection include the gas chromatograph (GC) and the mass spectrometer (MS). Because we would like to analyze isotope ratios of these gases, the preferred instrument for a multi-component volatiles detection mission is a combined Gas Chromatograph – Mass Spectrometer (GC-MS). However, other techniques that have been proven to meet the requirements will be considered.

1.2 Previous Work

The Regolith and Environment Science and Oxygen and Lunar Volatile Extraction (RESOLVE) project has included the development of a volatile detection instrument designed for hydrogen, water, and other relatively low molecular weight volatiles (e.g., CO, CO_2, He, N_2, CH_4, H_2S). The rationale for the original choice of a GC system over existing MS systems for RESOLVE included quantification problems that would result from the change in the gas viscosity with sample variation. If an MS alone is used, accurate quantification would require a large and complex calibration matrix (to correct for matrix effects), with sample carryover, particularly with water, still being a major issue. The other technical basis for the decision was the ability to accurately measure water vapor in the gas stream over a wide range of concentrations. NASA's research into MS system designs indicated that existing MS systems would not analyze water vapor because of the difficulty of getting a representative sample into the MS and clearing out residual surface water from the system.

1.3 Scope

The Contractor shall design and fabricate a vacuum development unit/protoflight gas chromatograph – mass spectrometer product for the National Aeronautics and Space Administration (NASA) to be delivered to the Kennedy Space Center (KSC). This document describes the technical specifications, which include a micro gas chromatograph coupled to a mass spectrometer that has the ability to obtain full mass spectrums (mass 0.8 Th to 68 Th) at a minimum rate of 6 Hz. The instrument shall be designed to quantify water, hydrocarbons, and inert components with a total analysis time of less than 3 minutes. The instrument shall be designed for use in a vacuum chamber and will be integrated by NASA into the RESOLVE Lunar Advanced Volatile Analysis (LAVA) Subsystem.

The nominal high-level concept of operation for this volatile analysis instrument is as follows:

a. A drill obtains a sample of regolith from the lunar surface.

b. The GC-MS instrument and fluid system are powered on and warmed up.

c. The regolith sample is delivered to the reactor vessel.

d. The reactor vessel is sealed and heat is applied to raise the temperature of the sample. Heating the sample evolves volatiles from the regolith sample and causes pressure to increase in the reactor vessel.

e. The fluid components transfer gas from the reactor to the inlet interface of the GC-MS instrument (either directly or via a surge tank).

f. The GC-MS analyzes the gas sample and within 5 minutes is ready to analyze the next sample. Duplicate or triplicate samples may be required. Data relaying the concentration of the top species of interest is transferred to the control system.

g. Raw data is transmitted and/or stored for downloading to the ground station when communication permits.

h. The reactor vessel continues to heat and evolve gas for analysis (steps a through g).

The first phase of this project will be the design of the Vacuum Development Unit (VDU) GC-MS. This design shall address the requirements and goals of the performance specifications in Section 3. The VDU GC-MS design will serve as the vacuum prototype development effort. Components should be spaceflight-rated components where required or have a path to flight (drop in replacement part) based on the Class D mission classification as described in NPR 8705.4 (http://nodis3.gsfc.nasa.gov/displayDir.cfm?t=NPR&c=8705&s=4). The governing document for the RESOLVE VDU will be Ames Procedural Requirements for Class D Spacecraft Design and Environmental Test (APR 8070.2). The design will address the requirements with verification being done through analysis and possibly some testing or evaluation of components or subassemblies. The vendor will work with NASA to define the specific interfaces that will allow the system to be integrated into the RESOLVE LAVA subsystem.

The design review cycle will consist of a 30% design review (PDR), a 60% review at the end of FY12, and a 90% design review (CDR) tailored for this instrument. The entrance and exit criteria of the PDR and CDR technical design review process can be found in NPR 7123.1A. The final design package shall be delivered at the conclusion of this phase of the project. This shall include the deliverables listed in the Statement of Work.

Upon successful completion of the instrument design, the option exists for NASA to go forward with the fabrication of the instrument according to the design documentation. Testing of the system shall be conducted as for a stand-alone instrument with initial checkout in a vacuum chamber. Because certain requirements should be tested during the buildup of the system, validation and verification tests shall be coordinated with NASA and conducted throughout the project. An acceptance test shall be performed to determine that the hardware meets the performance requirements. After delivery, NASA will integrate the GC-MS into the RESOLVE LAVA subsystem for integrated system operation.

2. APPLICABLE DOCUMENTS

2.1 Governmental

APR 8070.2	Ames Procedural Requirements
GSFC-STD-7000	General Environmental Verification Standard (GEVS) for GSFC Flight Programs and Projects
KSC-NE-8764	Crew Launch Vehicle (CLV) Mobile Launcher Solid Rocket Motor Exhaust Plume Induced Environment, Acoustic and Vibration, Volume I of II
KSC-STD-164	Environmental Test Methods for Ground Support Equipment, Standard for
KSC-STD-E-0002	Hazardproofing of Electrically Energized Equipment, Standard for
KSC-STD-E-0010	Soldering of Electrical Connections (Hand or Machine), Standard for
KSC-STD-E-0015	Marking of Ground Support Equipment, Standard for
MIL-C-5015	Connectors, Electrical, Circular Threaded, AN Type, General Specification for
MIL-DTL-83513	Connectors, Electrical, Rectangular, Microminiature, Polarized Shell, General Specification for
MIL-PRF-31032/1C	Printed Wiring Board, Rigid, Multilayered, Thermosetting Resin Base Material, With or Without Blind and Buried Plated – Through Holes, for Soldered Part Mounting
MIL-PRF-55110	Printed Wiring Board, Rigid, General Specification for
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-461	Requirements for the Control of Electromagnetic Interference Characteristics Requirements of Subsystems and Equipment

MIL-STD-810	Environmental Engineering Considerations and Laboratory Tests
MMPDS-06	Metallic Materials Properties Development and Standardization (MMPDS) Handbook
MSFC-SPEC-250	Protective Finishes for Space Vehicle Structures
NAS 5300.4(3J-1)	Workmanship Standard for Staking and Conformal Coating of Printed Wiring Boards and Electronic Assemblies
NASA-HDBK-7005	Dynamic Environmental Criteria
NASA-SPEC-5004	Welding of Aerospace Ground Support Equipment and Related Nonconventional Facilities
NASA-STD-8739.1	Workmanship Standard for Polymeric Application on Electronic Assemblies
NASA-STD-8739.2	Workmanship Standard for Surface Mount Technology
NASA-STD-8739.3	Soldered Electrical Connections
NASA-STD-8739.4	Crimping, Interconnecting Cables, Harnesses, and Wiring
NPD 8730.2C	NASA Parts Policy
NPR 7123.1A	NASA Systems Engineering Processes and Requirements
NPR 8705.4	Risk Classification for NASA Payloads

2.2 Non-Governmental

AIAA S-080	Space Systems – Metallic Pressure Vessels, Pressurized Structures, and Pressure Components
AIAA S-081	Space Systems – Composite Overwrapped Pressure Vessels (COPVS)

ANSI/ESD S20.20	Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)
ASTM E516	Standard Practice for Testing Thermal Conductivity Detectors Used in Gas Chromatography
ASTM E595	Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment
ATA NMF 100	National Motor Freight Classification, National Motor Freight Traffic Association, Inc.
IPC J-STD-001E	Requirements for Soldered Electrical and Electronic Assemblies
IPC J-STD-001ES	Space Applications Electronic Hardware Addendum to IPC J-STD-001E Requirements for Soldered Electrical and Electronic Assemblies
ISO 80000-1	Quantities and Units, Part 1: General
UFC 6000	Uniform Freight Classification – Rating, Rules, and Regulations
	Atlas V User's Guide
IPC J-STD-001E	Requirements for Soldered Electrical and Electronic Assemblies (with the exception of Chapter 10)
IPC J-STD-001ES	Space Applications Electronic Hardware Addendum to IPC J-STD-001E, Requirements for Soldered Electrical and Electronic Assemblies
ANSI/ESD S20.20	Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

(Copies of specifications, standards, drawings, and publications required by suppliers in connection with specified procurement functions should be obtained from the procuring activity or as directed by the contracting officer.)

3. SYSTEM REQUIREMENTS

3.1 RESOLVE System Requirements

The requirements listed in Appendix G apply to the total RESOLVE package, but some could be mitigated by design, packaging, and isolation of various effects for subsystems within the RESOLVE package, such as the LAVA Subsystem, which is composed of the GC-MS and Fluid Subsystem (FSS). System requirements that apply only to the GC-MS instrument in the LAVA Subsystem are covered in Section 3.2. For reference, the RESOLVE System requirements are shown in Appendix G.

3.2 LAVA GC-MS Subsystem Requirements

3.2.1 Sample Gas Temperature

3.2.1.1 The GC-MS shall operate with the analyte gases conditioned by the FSS. The sample gases entering the GC-MS will have been conditioned by the fluid sub-system (FSS) in the temperature range of 423 K to 430 K (150 °C to 157 °C). The FSS is a NASA design and is not part of this SOW.

3.2.2 Humidity

3.2.2.1 The instrument shall survive exposure to the relative humidity range of 0% to 80% in the temperature range of 288 K to 306 K (15 °C to 33 °C). These ranges are intended to cover standard laboratory conditions.

3.2.3 Shipping and Storage

3.2.3.1 Products shall be stored, preserved, marked, labeled, and packaged to prevent loss of marking, deterioration, contamination, excessive condensation and moisture, or damage during all phases of the program.

3.2.3.2 While in a shipping container, the GC-MS shall be wrapped in a non-ESD-generating vapor barrier with redundant maximum humidity indicators. Packaging materials and methods shall not degrade the molecular or particulate cleanliness of the item.

3.2.3.3 The shipping container shall also include shock and humidity indicators and shall be capable of prolonged shipping conditions.

3.2.4 Reliability

3.2.4.1 The instrument shall be designed for a minimum lifetime of 5000 hours of operation over a 2 year time period. This would include multiple startup and shutdown cycles. Reliability analysis will be used to support the design choices made to allow the unit to meet this requirement.

3.2.4.2 The instrument shall be designed for a continuous operation of 336 hours at a minimum.

3.2.4.3 The instrument shall be designed to perform for a minimum of 90 days without user intervention. This maintenance life-cycle design shall allow for 500 power cycles (with at least 50% of the power cycles being uncontrolled, hard cycles).

3.2.5 Gravity

3.2.5.1 The instrument shall be operated in a 1 g environment at a tilt of up to 15 degrees from the nominal operating orientation. This is the gravity expected during Earth-based testing of the instrument.

3.2.5.2 The instrument shall be designed to be operated in a 1/6 g (1.6 m/sec^2) environment at a tilt of up to 15 degrees from the nominal operating orientation. This is the gravity expected on the lunar surface.

3.2.6 Voltages

3.2.6.1 The instrument suite shall operate over the voltage range of 23 VDC to 36 VDC for load conditions from 0 to its rated capacity at 28 VDC. The voltage range is the expected range for the flight rover.

3.2.7 Vacuum

3.2.7.1 The instrument shall be able to survive the pressure range of 1.01×10^{-7} Pa to 1.01×10^{5} Pa (~1.45×10^{-11} psia to 14.7 psia). The instrument must be able to survive the pressure range from normal atmospheric conditions in the lab down to the lunar vacuum environment.

3.2.7.2 The instrument shall operate in the pressure range of 1.01×10^{-7} Pa (7.58×10^{-10} Torr) to 6.66×10^{-3} Pa (5×10^{-5} Torr) (~1.45×10^{-11} psia to 9.65×10^{-7} psia). The instrument will be designed to operate in a vacuum, it is expected that substantial mass savings can be obtained over lab designs.

3.2.8 Corona

3.2.8.1 Subsystems containing a high-voltage supply that are not tested through the corona region shall undergo venting/outgassing analysis to determine when it is safe to turn on and operate after launch. Each high-voltage supply is different in its design, and the voltage where coronal discharge may occur will vary by the construction and materials used. It will also be dependent on how clean the supply is and how well the outgassing products are vented to space.

3.2.8.2 The instrument and subsystems shall be designed to prevent corona or other forms of electrical breakdown at pressures between 6.66×10^{3} Pa and 6.66×10^{-2} Pa (9.67×10^{-1} psia to 9.67×10^{-6} psia). The instrument will NOT be operated in this range, but the instrument shall be designed to survive the transition through this range. This can be achieved by simply not powering the instrument during the transition if possible.

3.2.9 Pressure Decay

3.2.9.1 The instrument shall be designed to withstand a maximum atmospheric pressure decay rate (dp/dt) of -6.2×10^{3} Pa/sec (–0.9 psi/sec) for a period of not less than 10 seconds in a range from normal atmospheric pressure to 10 percent of normal atmospheric pressure. As the launch vehicle ascends, the instrument shall be designed to vent any nonpressurized cavities or spaces that are not sealed. A rapid depressurization can damage hardware if the design does not take this into account. These values are the worst-case scenario for the Atlas V launch vehicle. Verification by analysis is acceptable.

3.2.10 Structural Analysis and Design Factors of Safety

3.2.10.1 The instrument shall be capable of operating within specification after being subjected to quasi-static loads as defined in the physical mass acceleration curve (MAC) located in Appendix F of this document. Preliminary sizing of the primary (load-carrying) structure is based on load factors furnished by the launch vehicle organization. These load factors shall be applied at the center of mass and are based on design load databases, analyses of similar payloads, and flight data. The preliminary design of payload hardware or equipment items commonly use load factors obtained from a physical MAC. This is to be considered the worst-case scenario until further analysis can provide more accurate levels. Verification by analysis is acceptable.

3.2.10.2 Structural analysis and design factors of safety shall apply to all systems in accordance with APR 8070.2, Section 3.2.1.3, as shown in Appendix C. Proper factors of safety will result in a more robust design.

3.2.11 Thermal

3.2.11.1 The instrument shall be capable of operating over the temperature range of 273 K to 323 K (0 °C to 50 °C). Heaters, blankets, etc., may be used to maintain a safe operating temperature for the instrument. Additionally, cooling will be available if needed. The instrument designer shall determine the cooling needs and verify with the Contracting Officer Technical Representative (COTR) that sufficient capacity is available in the RESOLVE design.

3.2.11.2 The instrument shall be capable of surviving over the temperature range of 233 K to 323 K (–40 °C to 50 °C). Heaters, blankets, etc., may be used to maintain a safe operating temperature for the instrument. Additionally, cooling will be available if needed. The instrument designer shall determine the cooling needs and verify with the COTR that sufficient capacity is available in the RESOLVE design.

3.2.11.3 Material allowable stress values shall account for operational temperature properties, deterioration of material properties caused by previous temperature exposure, and/or radiation degradation. Thermal effects on material properties must be addressed to provide proper safety margins.

3.2.11.4 Thermal design shall provide adequate margin between stacked worst-case flight predictions and component allowable flight temperature limits in accordance with APR 8070.2, Section 3.4. Positive temperature margins are required to account for uncertainties in power dissipations, environments, and thermal system parameters.

3.2.11.5 The instrument shall provide one thermal interface as specified in the Interface Control Document and specify the heat flow required for operation in the specified thermal environment. As a goal, heat loss should be minimized.

3.2.12 Mass

3.2.12.1 The total mass for the instrument shall be equal to or less than 7 kg. This is the mass allocated for flight.

NOTE

This mass requirement does NOT include the carrier gas tank or regulators.

3.2.12.2 The total goal mass for the instrument should be equal to or less than 5 kg. This is the target flight mass.

3.2.13 Volume

3.2.13.1 The maximum overall volume for the instrument shall be less than or equal to 18,000,000 cubic millimeters (0.018 cubic meters). This is the volume allocated for flight.

3.2.13.2 The goal is to minimize volume. The maximum overall dimensions for the instrument should be equal to or less than 250 × 250 × 175 mm. (Dimensions are in millimeters.)

NOTE

This volume requirement does NOT include the carrier gas tank or regulators.

3.2.14 First Mode

3.2.14.1 The first fundamental frequency of the instrument shall be greater than 100 Hz when the instrument is constrained in a fixed-base condition through the instrument mounting points. This is to avoid coupling with spacecraft or launch vehicle structural modes. Verification by analysis is acceptable.

3.2.15 Redundancy

3.2.15.1 The instrument shall be designed as zero-fault tolerant and fail-safe. Redundancy is not required; however, the instrument shall be designed so that a failure will not result in an unsafe condition. This includes, but is not limited to, hazards such as those created by pressure systems, heaters, high-voltage supplies, etc.

3.2.15.2 Redundant functions shall be implemented so that no credible single-point failure anywhere in the system will result in unacceptable degradation of the redundant side. When cross-strapping, the design shall avoid routing of redundant signals through a single connector, relay, or integrated circuit. Although redundancy can greatly enhance system reliability and confidence, it also adds complexity to the overall design. Designs must take into consideration the complexity that is added by redundant components in order to mitigate potential negative effects on the overall system reliability. Analysis of cross-strapping networks, using a failure mode, effects, and criticality analysis (FMECA) or other techniques, is essential for these types of systems.

3.2.16 Dust Tolerance

3.2.16.1 The instrument shall operate within specification when the sample gas contains particulates less than or equal to 10 μm (microns). The fluid system providing the sample gas to the instrument will have filters to limit the size of particulates in the sample gas.

3.2.17 System Vent Crosstalk

3.2.17.1 The LAVA Subsystem shall be designed such that the internal handling of samples and the venting of gases does not interfere with system operation (such items include, but are not limited to, measurement accuracy and scan times).

4. GAS CHROMATOGRAPHY SUBSYSTEM REQUIREMENTS

4.1 General Description

The Gas Chromatography (GC) Subsystem will be used to separate a gas phase sample mixture derived from heating lunar regolith or suitable simulant mixtures in a closed reactor or the gas phase by-products produced from reacting the regolith or simulant with hydrogen in the same reactor. Samples will preferably be drawn from the intermediate surge tank assembly with a defined volume, pressure, and temperature, where the contents of the surge tank will be quantitatively determined by the GC analysis and its detectors (including an MS and thermal conductivity detectors (TCDs)), along with the state data from the surge tank. When low pressures in the oven would not permit sampling from the surge tank, the GC may also be required to sample directly from the reactor, but quantitation will be limited by knowledge of the gas phase state in the reactor and the possibly inconsistent concentrations in the reactor. The GC Subsystem shall also accept a calibration gas mixture of known concentration to allow validation of operation and adjustment of response factors to compensate for any drift in the GC output. The gas separations will include permanent gases and gas phase components up to mass 64 Th (SO_2), and can be accomplished with either separate GC subsystems with multiple columns, or multiple columns separated by column switching, but all stationary phases must be protected from damage by expected components by either column switching, guard columns, or backflushing of components that might change the retention characteristics of the analytical columns. Each analytical column shall have a dedicated TCD, and the effluent from the analytical columns shall be sent to a single MS detector (separately specified). The eluent peaks from separate analytical columns should be separated in time from each other as they enter the single MS. The instrument shall be capable of bypassing the GC columns and delivering sample directly to the MS. This is a backup mode of operation that will only be used in certain circumstances.

4.2 Details

4.2.1 Components to be Separated and Quantified in the GC

4.2.1.1 Hydrogen, helium, carbon monoxide, carbon dioxide, methane, nitrogen, oxygen, argon, ammonia, hydrogen sulfide, and sulfur dioxide at concentrations of 1000 ppm to 99% in the gas phase shall be separated and quantified in the GC. If neon is used as the carrier gas, the detection limit for methane shall be increased to 1500 ppm on the TCD because of the narrow thermal conductivity difference between neon and methane. The MS detection limits would remain at 1000 ppm.

4.2.1.2 The GC-MS instrument shall detect and quantify water at concentrations of 5000 ppm to 95% in the gas phase. This means that the injection system and column temperatures must be high enough to prevent condensation of 100% water vapor at the column pressure. (Target: 1000 ppm to 100%.)

4.2.1.3 Resolution of the adjacent peaks is important for the overall analysis. The instrument shall provide baseline resolution for the target components listed in 4.2.1.1 on the analytical columns where they will be analyzed. Baseline separation of these components is required for subsequent MS analysis, including possible isotope ratio analysis of H/D and O-16/O-18 in the listed compounds.

Baseline resolution is defined as follows:

The resolution of two species, A and B, is defined as

Where t_R is the retention time, and W is the peak width at baseline. Baseline resolution is achieved when R = 1.5.

4.2.1.4 Baseline separation of H_2 and He is a goal for possible analysis for He-3, apart from HD that might also exist in the sample.

4.2.2 Carrier Gas Inlet

4.2.2.1 The contractor shall specify inlet pressure requirements and total flow rate at standard temperature and pressure (STP).

4.2.2.2 The contractor shall provide the 1/16" bulkhead tubing fitting(s) with wrench clearance for attaching a compatible tube and nut.

4.2.2.3 The contractor shall use a high purity metal to metal seal for this interface.

4.2.2.4 The contractor shall specify the carrier gas(es) and justify this selection.

4.2.3 Sample Inlet and Column Injection System

4.2.3.1 The Sample Inlet and Column Injection System shall operate at a temperature that will prevent the condensation of water vapor saturated at 150 °C.

4.2.3.2 The Sample Inlet and Column Injection System shall allow the sample to bypass the chromatographic columns and be analyzed by the MS without separation.

4.2.3.3 The Sample Inlet shall be designed to accept gas samples from the FSS from 0 to 100 psia.

4.2.3.4 The Sample Inlet and Column Injection System shall minimize any possible cross talk between the direct MS injection and chromatographic separation and subsequent MS analysis. The limits of detection must be met as an integrated system.

4.2.3.5 The Sample Inlet and Column Injection System shall allow the programming of variable sample volumes with a ratio of largest to smallest of at least 5 and preferably 10 in a sample volume compatible with the analytical columns selected.

4.2.3.6 The Sample Inlet and Column Injection System shall be independent of sample viscosity.

NOTE

The Sample Inlet and Column Injection System shall NOT utilize an apparatus that varies the sample volume when sample viscosity changes, such as pressure flow through an orifice.

4.2.4 Column Temperature Controls

4.2.4.1 The column temperature controls shall be programmable by the operator.

4.2.4.2 If guard columns with backflushing are used to prevent water vapor from entering the analytical column, they shall be separately heated in accordance with Section 4.2.1.2.

4.2.4.3 Heater cycling shall not affect the elution times of the components ($\Delta\ t_R$ <0.1W). Temperature shall be tightly controlled such that elution times are not affected ($\Delta\ t_R$ <0.1W) by on/off cycling of the column heater controls.

4.2.4.4 The analytical column separating the permanent gases shall require a separate lower temperature than the water analytical column, and shall be separately controlled. The temperature range for this column is anticipated to be 40 °C to 80 °C. The column oven design shall be executed with sufficient isolation from other heat sources to achieve any selected temperature in this range. Lower temperatures may be used if desired.

4.2.5 Analytical Column Selection

4.2.5.1 The analytical column shall complete all required component elutions to the detector in 180 sec or less. Any backflushing shall be completed within 4 min.

4.2.5.2 Carrier gas consumption shall be less than 3 sccm for any individual column, with the goal of minimizing overall carrier gas consumption.

4.2.5.3 Columns selected may be capillary, megabore, or packed microbore as long as other requirements are met.

4.2.5.4 The method of replacing the columns shall be specified.

4.2.6 Thermal Conductivity Detectors

4.2.6.1 TCDs shall be connected to the elution end of each analytical column.

NOTE

TCDs may also be mounted directly after injection and where backflushed gases vent. This allows monitoring of the injection cut and backflushed components.

4.2.6.2 The TCD shall have a working volume of < 2ųL and a response time < 0.1 sec in accordance with ASTM E516, Revision 95A, using the column flow rate designated for each column.

4.2.6.3 The TCD shall prevent burnout of the TCD filament in the case of a loss of carrier gas flow.

NOTE

Carrier gas flow can be lost or reduced by leaks at various points as well as an empty carrier gas tank, or even operator error. The TCDs shall be driven using a constant resistance circuit, instead of a constant current or constant voltage circuit, to prevent burnout of the TCD filament in all cases of loss or reduction of carrier gas flow.

4.2.6.4 The TCD shall have detector noise, measured as +/– 3σ, of less than 200 ppm of any target component listed in 4.2.1.1 in the chosen carrier gas.

4.2.6.5 The TCD body temperature control shall be programmable and be able to operate at temperatures up to 160 °C.

4.2.6.6 The method of replacing TCDs shall be specified and a detailed procedure shall be included in the operations manual.

4.2.7 GC peak Integration of TCD and MS signals

4.2.7.1 The contractor shall describe the peak integration software for both the TCD and MS signals

4.2.7.2 The software shall offer as a minimum automated peak detection, user adjustable parameters for slope detection for peak onset and end of integration, automated baseline construction using linear connection of the start and stop points of the peak, user adjustment of peak integration start and stop times, peak skimming for closely eluting peaks where a following peak may appear on the tail of a preceding peak, automated valley detection and peak area separation via vertical drops to the constructed baseline and other options typical of GC integration software.

4.2.7.3 The integration software capabilities shall be addressed for both the TCD and MS signals, and any differences in the software capabilities for these two signals described in detail.

4.2.7.4 The ability of the peak integration software to be adjusted to accommodate standard and unusual peak integration capabilities will be part of the proposal evaluation criteria.

4.2.8 Materials in Contact with the Gas Streams

4.2.8.1 All materials of construction in contact with the gas stream shall be inert to reaction with hot water vapor. The test for this requirement will be to operate the GC on a sample containing 10% water vapor by volume. Over the course of injecting 50 such samples:

a. The quantitative response to water vapor shall not change by more than 5% of the initial injection.

b. The minimum detection limits for water shall not increase beyond the specified detection limits in Section 4.2.1.2.

4.2.8.2 All construction materials that come into contact with the gas stream shall be inert to reaction with the sample components listed in Section 4.2.1. Reactivity within the GCMS would remove the molecules being analyzed, affecting the analysis and degrading future results.

4.2.9 Carrier Gas Storage and Delivery System

NOTE

The carrier gas supply bottle(s) will need to have sufficient capacity to allow 14 days of analysis. For a flight-like system, a very high pressure tank would likely be used. The design of such a tank (up to 6000 psi) and the first stage regulator is considered part of the fluid subsystem of the LAVA Subsystem.

4.2.9.1 The carrier gas inlet requirements (pressure, flow rate, gas purity, and gases to be supplied) shall be specified.

4.2.9.2 Total flow rate of the carrier gas(es) shall not exceed 20 sccm, with lower flow rates a goal.

4.2.9.3 The gas connection line to the carrier gas flow control system shall be supplied and shall be 1/16" OD.

4.2.9.4 The carrier gas flow shall be heated to the injector temperature before the point of injection to prevent water condensation.

NOTE

Results of experiments at NASA/KSC have shown that all of the gases to be analyzed can be done on a GC with TCDs using neon as the carrier gas. Better sensitivity may be possible with other carrier gases, at the expense of additional weight for two tanks and gas control systems.

5. MASS SPECTROMETER SUBSYSTEM

The LAVA instrument shall have a Mass Spectrometer (MS) Subsystem, which shall have the following characteristics.

5.1 MS Design

5.1.1 Pneumatic Interface

5.1.1.1 The MS Subsystem shall be designed to analyze sample input from the Gas Chromatograph Subsystem and an internal sample input that has bypassed the GC columns (not simultaneously). The MS Subsystem shall be designed to accept sample input that has bypassed the GC Subsystem. (One interface between the FSS and GC-MS will deliver samples to the instrument. The instrument must be capable of bypassing the GC columns and analyzing the sample directly in the MS.)

5.1.1.2 The GC effluent inlet into the MS shall be designed to handle the full range of detection required by the system.

5.1.1.3 The GC-MS bypass inlet shall be designed for direct injection of gases from the sample inlet of the GC-MS. This direct injection serves as a backup should the GC Subsystem have a failure that prevents analysis through the GC Subsystem.

5.1.2 Mass Spectral Range

5.1.2.1 The MS Subsystem shall be designed to measure ions in the range of at least 0.8 to 68 Thompson.

NOTE

A Thompson, Th, is a mass-to-charge ratio unit and is defined as the ratio of one-twelfth the mass of a carbon-12 atom to the charge of an electron.

5.1.3 Detector

5.1.3.1 The MS Subsystem shall be designed to have a detection scheme (via ionization parameters, mass scanning parameters, and detection parameters) capable of 5 orders of magnitude dynamic range. This shall be verified by inspection of the design and drawings provided by the vendor of the ionization, scanning, and detection electronics as well as drawings and documents of the physical layout of the vacuum chamber components with machining accuracy and precision associated with the components.

NOTE

If a linear A/D converter is used to achieve this, it shall correspond to 18 bits (262,144; 5.4 orders of magnitude) or higher.

5.1.4 Benchtop Verification

5.1.4.1 The MS Subsystem shall be designed so that it can undergo verification testing under terrestrial environments with the addition of commercially available products (vacuum components, pumps). This shall be verified by inspection of a test plan provided by the vendor.

5.1.5 Ambient Environment

5.1.5.1 The MS Subsystem shall be designed without pumps for sample transport, analyzer operation, detector operation, sample carryover removal, or any other operation. The system will be operated in a vacuum environment which it will not have to provide.

5.1.5.2 The MS Subsystem shall be designed to operate in the GC mode or the Isotope Resolution mode in an ambient pressure ranging from a maximum of 1.33×10^{-4} Pa (1×10^{-6} Torr) to a minimum 1.33×10^{-9} Pa (1×10^{-11} Torr). For the Degraded Vacuum mode, ambient pressures up to 6.66×10^{-3} Pa (5×10^{-5} Torr) shall be allowed with degraded performance.

5.1.5.3 The MS Subsystem shall be designed to operate with vacuum temperatures as specified in Section 3.2.10. Thermal management shall not use convective methods.

5.1.6 MS Design – Higher Level Assembly Requirements

5.1.6.1 The MS Subsystem shall be designed to meet the requirements of the higher level assembly (the GS-MS/LAVA instrument) without additional interfacing equipment.

SPECIFIC EXAMPLES

The MS shall be designed to meet specifications for vibration/acoustics without additional dampeners when integrated to LAVA instrument. The MS shall be designed to use existing power (nominal 28 V) without converters/inverts that would put an electric and thermal tax on the system. If the MS Subsystem is designed independently of the GC Subsystem, the MS Subsystem shall be designed as MIL-STD-461 EMI-compliant; otherwise, the GC-MS assembly shall be designed as MIL-STD-461 EMI-compliant.

5.2 MS Performance

5.2.1 Start-up Time

5.2.1.1 Within 15 minutes, the mass spectrometer subassembly shall be capable of scanning the entire mass range with a mass accuracy of 0.1 Th and signal accuracy of ±(1,000 ppm absolute + 10% of reading). Within 30 minutes, all requirements shall be met.

5.2.2 Operational Modes

5.2.2.1 The MS Subsystem shall be able to provide operating modes for three applications. The subsystem does not actually need three different modes, but the unit shall not require more than three modes to meet the performance specifications herein. For the purposes of this document, these three modes will be called “GC Scan Mode,” “Isotope Resolution Mode,” and “Degraded Vacuum Mode.” The vendor may use any terminology consistent with the field of mass spectrometry.

5.2.2.2 All requirements associated with each operating mode shall be met simultaneously. Unless otherwise stated, no adjustment to the operating parameters shall be made during continuous operation/testing of an operating mode. (For example, such an exclusion occurs during a GC scan, when the eluted component is reproducible. A sequence of reproducible parameter adjustment may be of interest to the designer/end-user.)

5.2.3 Spectral Range – GC Scan Mode

5.2.3.1 The MS Subsystem shall scan from a minimum of 0.8 Th to 68 Th.

5.2.4 Signal (Mass) Resolution – GC Scan Mode

5.2.4.1 The MS Subsystem shall be able to resolve two adjacent peaks where the peak maxima are less than 1.1 Th apart, the smaller peak is less than 1% the intensity of the primary, and the valley between the adjacent peaks is less than 10% of the smaller peak.

5.2.4.2 The peak width across the entire scan spectrum shall be less than 0.3 Th at 10% maximum.

5.2.5 Signal Dynamic Range and Resolution – GC Scan Mode

5.2.5.1 The MS Subsystem shall have a quantitative signal dynamic range of at least 4 orders of magnitude with a resolution of at least 5% relative. The unit shall be capable of quantifying at least 1,000 ppm up to 100% concentration.

5.2.6 Component Dynamic Range – GC Scan Mode

5.2.6.1 The MS Subsystem shall be able to detect and measure the components listed in Table 1 in a background of hydrogen, helium, neon, and/or argon.

Table 1. GC Scan Mode Dynamic Range

Component	Lower Limit of Detection	Upper Detection Limit
Hydrogen	1,000 ppm	99%
Helium	1,000 ppm	99%
Methane	1,000 ppm	99%
Ammonia	1,000 ppm	99%
Water	5,000 ppm	95%
Nitrogen	1,000 ppm	99%
Carbon monoxide	1,000 ppm	99%
Oxygen	1,000 ppm	99%
Hydrogen sulfide	1,000 ppm	99%
Argon	1,000 ppm	99%
Carbon dioxide	1,000 ppm	99%
Sulfur dioxide	1,000 ppm	99%

NOTE

The limit of detection (LOD) shall be verified by using 2 sample mixtures (low and test) where the low concentration is two to four times the LOD and the test concentration is five to 10 times the LOD. Then the LOD is calculated (baseline adjusted) using the S/N=3 definition, as provided in the following equation, where sigma is the standard deviation (of the sample, N-1) of the raw data set, *X* is the average signal intensity of the raw data set, and "True" is the certified concentration of the gas in the calibration bottle.

$$C_{LOD} = 3 \cdot \left[\frac{\sigma_{Gas,Btl}}{X_{Gas,Btl} - X_{Gas,Low}} \right] \cdot \left([True]_{Gas,Btl} - [True]_{Gas,Low} \right)$$

5.2.7 Component Resolution – GC Scan Mode

5.2.7.1 The MS Subsystem shall resolve the following ion species under the conditions listed in Table 2 (keeping in mind the carrier gas).

Table 2. GC Scan Mode Resolution Pairs

Dominant Ion	Trace Ion	Inlet Gas Mixture
${}^{1}H_2^{+}$ (2 Th)	${}^{4}He^{+}$ (4 Th)	> 20% H_2; < 500 ppm He
${}^{1}H_2^{+}$ (2 Th)	${}^{4}He^{+}$ (4 Th)	< 500 ppm H_2; > 20% He
${}^{14}N_2^{2+}$ (14 Th)	${}^{16}O_2^{2+}$ (16 Th)	> 60% N_2; < 500 ppm O_2
${}^{1}H_2{}^{16}O^{+}$ (18 Th)	HO^{+} (17 Th)	Any

5.2.8 Accuracy – GC Scan Mode

5.2.8.1 The total accuracy (summation of absolute and relative accuracy) for all components measured shall be ±(500 ppm absolute + 5% of reading) for all components listed in the "Component Dynamic Range – GC Scan Mode" specification, except ammonia and water. Ammonia and water shall have a total accuracy of ±(500 ppm absolute + 15% of reading).

5.2.9 Precision – GC Scan Mode

5.2.9.1 The total precision (summation of absolute and relative precision) for all components measured shall be ±(200 ppm absolute + 2% of reading).

<u>NOTE</u>

For the purposes of this specification, precision is defined as the Gaussian standard deviation of 10 consecutive measurements of stable gas.

5.2.10 Duty Cycle – GC Scan Mode

5.2.10.1 The MS Subsystem shall measure all components, and provide the resulting signal to the higher level assembly in less than 165 msec.

5.2.11 Response Time Drift – GC Scan Mode

5.2.11.1 In GC Scan Mode, the MS Subsystem's response time shall not drift more than 50 msec during 8 hours. The response time is defined as the period between the time at which an external event changes the samples delivered to the mass spectrometer and the time at which the new sample meets the accuracy specification.

5.2.12 Mass Resolution – Isotope Resolution Mode

5.2.12.1 In Isotope Resolution Mode, the MS Subsystem shall be capable of resolving (at most 25% valley of the smaller abundance peak) the components listed in Table 3, Section 5.2.13.1.

5.2.13 Dynamic Range – Isotope Resolution Mode

5.2.13.1 In Isotope Resolution Mode, the MS Subsystem shall be able to measure the following components (see Table 3) with concentrations in the range of 1,000 ppm up to 99%.

Table 3. Isotope Resolution Components

Component	Mass (Da)		Component	Mass (Da)
$^{1}H_2$	2.016		$^{12}C^{16}O$	27.995
$^{1}H\,^{2}H$	3.022		$^{13}C^{16}O$	28.998
Helium-4	4.003		$^{1}H_2\,^{32}S$	33.9877
$^{12}C^{1}H_4$	16.03		$^{1}H_2\,^{34}S$	35.98
$^{13}C^{1}H_4$	17.03		Argon-36	35.97
$^{1}H_2\,^{16}O$	18.01		Argon-38	37.96
$^{1}H_2\,^{18}O$	20.01		Argon-40	39.96
$^{14}N_2$	28.006		$^{12}C^{16}O_2$	43.99
$^{14}N\,^{15}N$	29.003		$^{13}C^{16}O_2$	44.993
$^{16}O_2$	31.99		$^{32}S^{16}O_2$	63.96
$^{16}O^{18}O$	33.994		$^{34}S^{16}O_2$	65.96

5.2.14 Accuracy – Isotope Resolution Mode

5.2.14.1 The total accuracy (summation of absolute and relative accuracy) for all components measured shall be ±(100 ppm absolute + 5% of reading) for all components listed in Table 3.

5.2.15 Precision – Isotope Resolution Mode

5.2.15.1 The total precision (summation of absolute and relative precision) for all components measured shall be ±(50 ppm absolute + 2% of reading).

NOTE

For the purposes of this specification, precision is defined as the Gaussian standard deviation of 10 consecutive measurements of stable gas.

5.2.16 Duty Cycle – Isotope Resolution Mode

5.2.16.1 The MS Subsystem shall measure all components within 1.5 ± 0.5 seconds.

5.2.17 Accuracy – Degraded Vacuum Mode

5.2.17.1 The total accuracy (summation of absolute and relative accuracy) shall be ±(500 ppm absolute + 20% of reading) for all components listed in the “Component Dynamic Range – GC Scan Mode” specification, except ammonia and water. Ammonia and water shall have a total accuracy of ±(500 ppm absolute + 30% of reading).

5.2.18 Duty Cycle – Degraded Vacuum Mode

5.2.18.1 The mass spectrometer subsystem shall measure all components within the mass range of 0.8 Th to 68 Th at the detection limits in less than 500 msec.

6. SOFTWARE INTERFACE

6.1 Communication Interface

6.1.1 Command and Data Transfer

6.1.1.1 The VDU GC-MS instrument shall provide an external interface for command and data and state transfer using Object Management Group (OMG)-compliant Data-Distribution Service (DDS) for Real-Time Systems middleware. The DDS shall be compatible with Twin Oaks CoreDX DDS. Externally initiated commands shall use a DDS Quality of Service (QOS) of “Reliable” while data and state information published to DDS shall use a QOS of “Best Effort.”

6.1.2 Interface Definition

6.1.2.1 GC-MS shall subscribe to DDS commands and publish state and data via DDS as defined in valid interface definition language (IDL) files, which shall be provided electronically and by hard copy no later than upon the delivery of the instrument.

6.1.3 Command Capability

6.1.3.1 The commands made available through the external interface should, at a minimum, allow for the same level of instrument control as the vendor-provided user interface. GC-MS closed-loop and other low-level controls should not require external participation. All externally initiated commands that are successfully executed shall result in the publishing of an associated acknowledgment message.

6.1.4 Data Publishing

6.1.4.1 All processed instrument data shall be published to DDS in near real time.

6.1.5 Data Logging

6.1.5.1 Raw data files for 150 analysis runs shall be logged locally on the GC-MS instrument. Logged data as specified by time period shall be published to DDS in response to an external DDS request.

6.1.6 State Reporting

6.1.6.1 The state or mode of the instrument and significant subsystems shall be published to DDS periodically and upon any change in state.

6.1.7 Timing

6.1.7.1 All locally logged data and anything published to DDS shall be time-stamped with timing synchronized using the Network Time Protocol (NTP).

6.1.8 Network Interface

6.1.8.1 A 10BASE-T or 100BASE-T Ethernet interface shall be provided.

7. ELECTRICAL

7.1 General Electrical Workmanship

7.1.1 Standards

7.1.1.1 The contractor shall design and manufacture according to the following documents:

a. IPC J-STD-001E, Requirements for Soldered Electrical and Electronic Assemblies (with the exception of Chapter 10)

b. NASA-STD-8739.1, Workmanship Standard for Polymeric Application on Electronic Assemblies (Revision A with Change 2 of 3/29/2011)

c. IPC J-STD-001ES, Space Applications Electronic Hardware Addendum to IPC J-STD-001E, Requirements for Soldered Electrical and Electronic Assemblies

d. NASA-STD-8739.4, Crimping, Interconnecting Cables, Harnesses, and Wiring (Baseline with Change 6 of 3/29/2011)

e. MIL-PRF-31032/1C, Printed Wiring Board, Rigid, Multilayered, Thermosetting Resin Base Material, With or Without Blind and Buried Plated – Through Holes, for Soldered Part Mounting

f. ANSI/ESD S20.20, Protection of Electrical and Electronic Parts, Assemblies and Equipment (Excluding Electrically Initiated Explosive Devices)

7.1.2 Power

7.1.2.1 Peak power shall be less than or equal to 75 W with a goal of less than 50 W peak power.

7.1.2.2 Average power, defined as the power time-averaged from cold start to the completion of one sample and analysis cycle, shall be less than or equal to 30 W with a goal of less than or equal to 20 W.

7.1.3 Connectors

7.1.3.1 Connectors shall be suitable for aerospace use, meeting MIL-DTL specifications with materials compatible with a space environment.

7.1.4 Electromagnetic Interference

7.1.4.1 The instrument and subsystems shall comply with EMI/EMC requirements in accordance with Appendix B. Appendix B references APR 8070.2, Table 4.4.2-1 (provided), and shall ensure that the payload will not generate potentially damaging electromagnetic interference and that the instrument will not be susceptible to emissions that could adversely affect its safety and performance. Verification by analysis is acceptable where applicable.

7.1.5 Radiation

7.1.5.1 Electronics shall be shielded with a minimum of 2.54 mm of aluminum.

7.1.5.2 Electronics and software shall be designed to mitigate the effects of single event upsets and latch-up.

7.1.5.3 Written descriptions of mitigation methods for the effects of single event up-sets and latch-up shall be provided to the customer upon delivery of the instrument.

7.1.6 Components

7.1.6.1 A complete Bill of Materials of all components, parts, and materials shall be provided upon delivery of the instrument.

7.1.6.2 As a minimum, the Bill of Materials shall provide the item description, manufacturer's part number, manufacturer's lot number, supplier, supplier's part number, date purchased, and component designator (if applicable).

APPENDICES

APPENDIX A. VIBRATION

The figure below provides generalized random vibration test levels for ELV components of 22.7 kg (50 lb) or less.

Frequency (Hz)	ASD Level (g^2/Hz) Qualification	Acceptance
20	0.026	0.013
20-50	+6 dB/oct	+6 dB/oct
50-800	0.16	0.08
800-2000	-6 dB/oct	-6 dB/oct
2000	0.026	0.013
Overall	14.1 G_{rms}	10.0 G_{rms}

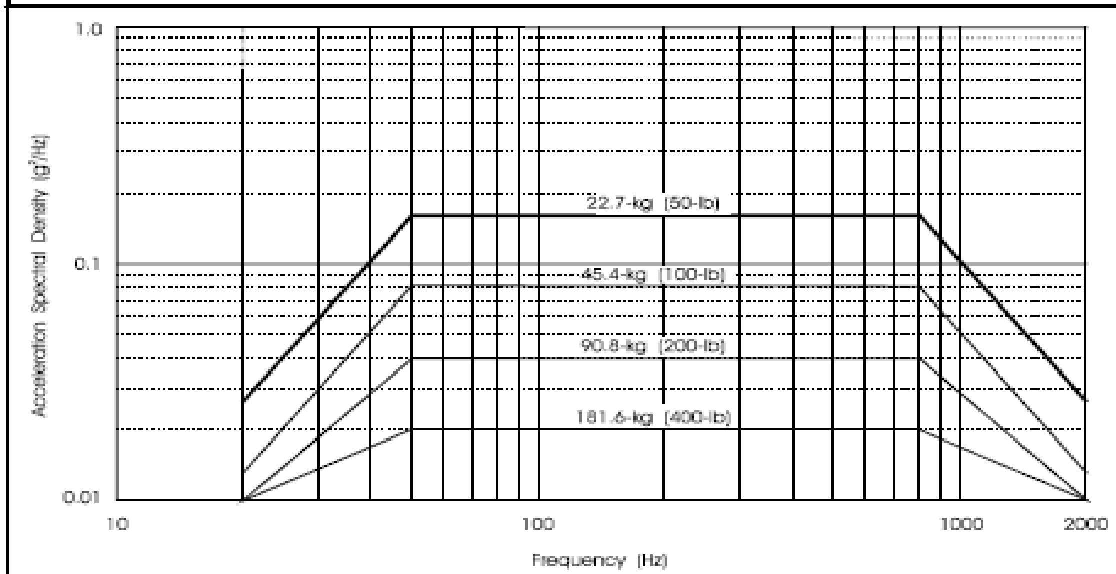
The acceleration spectral density level may be reduced for components weighing more than 22.7-kg (50 lb) according to:

	Weight in kg	Weight in lb	
dB reduction	= 10 log(W/22.7)	10 log(W/50)	
$ASD_{(50\text{-}800\ Hz)}$	= 0.16•(22.7/W)	0.16•(50/W)	for protoflight
$ASD_{(50\text{-}800\ Hz)}$	= 0.08•(22.7/W)	0.08•(50/W)	for acceptance

Where W = component weight.

The slopes shall be maintained at + and - 6dB/oct for components weighing up to 59-kg (130-lb). Above that weight, the slopes shall be adjusted to maintain an ASD level of 0.01 g^2/Hz at 20 and 2000 Hz.

For components weighing over 182-kg (400-lb), the test specification will be maintained at the level for 182-kg (400 pounds).



APPENDIX B. EMI

Type	Test	Paragraph Number*	Component	Subsystem/ Instrument
CE	Dc power leads	4.4.2.1.a&c	R	R
CE	Power Leads	4.4.2.1.b	R	R
CE	Antenna terminals	4.4.2.1.d	R	-
RE	Ac magnetic field	4.4.2.2.a	R	R
RE	E-fields	4.4.2.2.b&c	R	R
RE	Payload transmitters	4.4.2.2.d	Note 1	Note 1
RE	Spurious (transmitter antenna)	4.4.2.2.e	-	R
CS	Power line	4.4.2.3.a	R	R
CS	Intermodulation products	4.4.2.3.b	R	-
CS	Signal rejection	4.4.2.3.c	R	-
CS	Cross modulation	4.4.2.3.d	R	-
CS	Power line transients	4.4.2.3.e	R	R
RS	E-field (general compatibility)	4.4.2.4.a	R	R
RS	Magnetic-field susceptibility	4.4.2.4.b	R	R

CE	Conducted Emission
CS	Conducted Susceptibility
R	Test to ensure reliable operation of payload, and to help ensure compatibility with the launch vehicle and launch site
RE	Radiated Emission
RS	Radiated Susceptibility
*	APR 8070.2

APPENDIX C. TEST OF FACTORS OF SAFETY

Flight Hardware Design/Analysis Factors of Safety Applied to Limit Loads [1,2]			
Type	Static	Sine	Random/Acoustic[4]
Metallic Yield	1.25[3]	1.25	1.6
Metallic Ultimate	1.4[3]	1.4	1.8
Stability Ultimate	1.4	1.4	1.8
Beryllium Yield	1.4	1.4	1.8
Beryllium Ultimate	1.6	1.6	2.0
Composite Ultimate	1.5	1.5	1.9
Bonded Inserts/Joints Ultimate	1.5	1.5	1.9

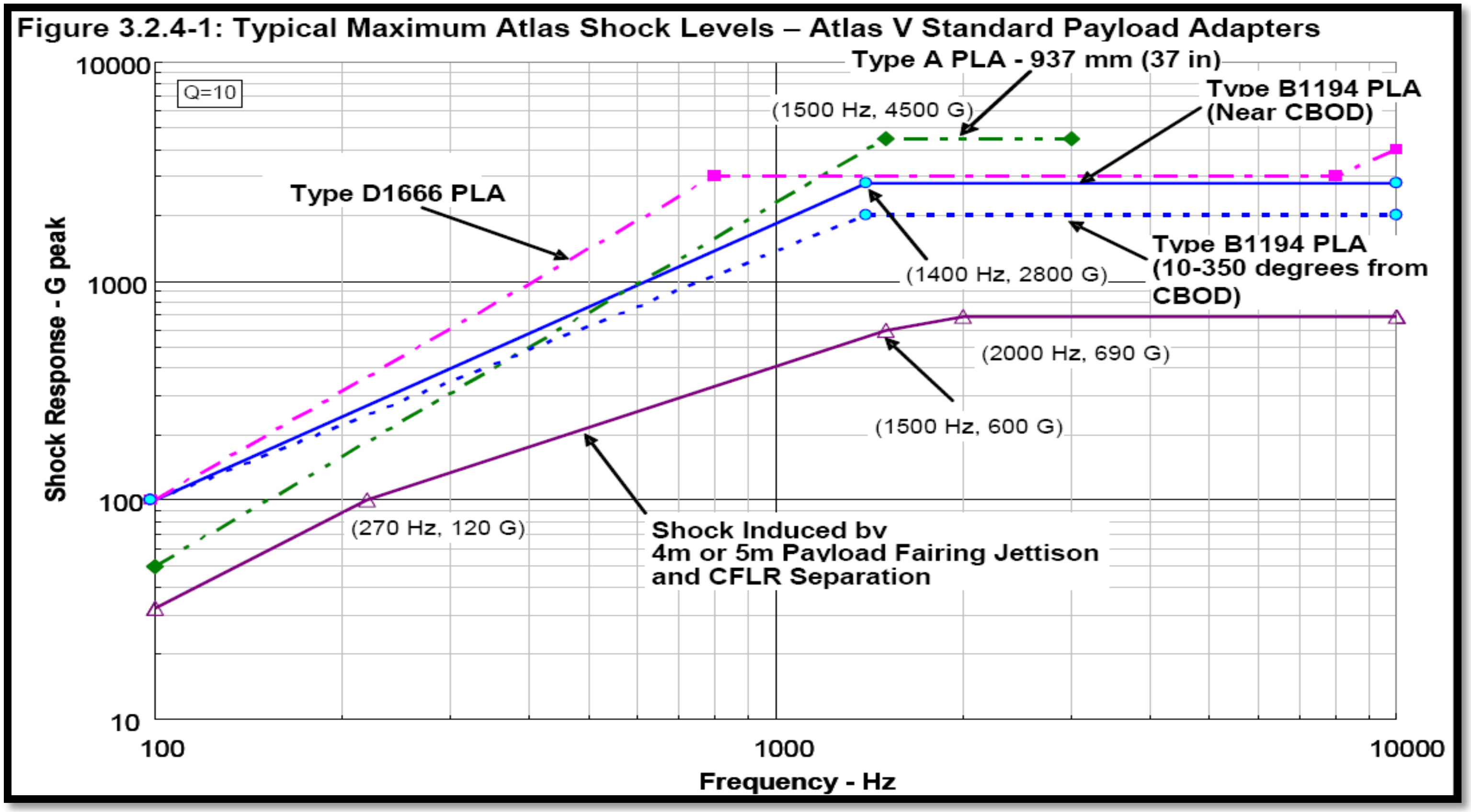
1 – Factors of safety for pressurized systems to be compliant with Range Safety documentation.
2 – Factors of safety for glass and structural glass bonds specified in NASA-STD-5001
3 – If qualified by analysis only, positive margin must be shown for factors of safety of 2.0 on yield and 2.6 on ultimate.
4 – Factors shown should be applied to statistically derived peak response based on RMS level. As a minimum, the peak response shall be calculated as a 3-sigma value.

APPENDIX D. ACOUSTIC

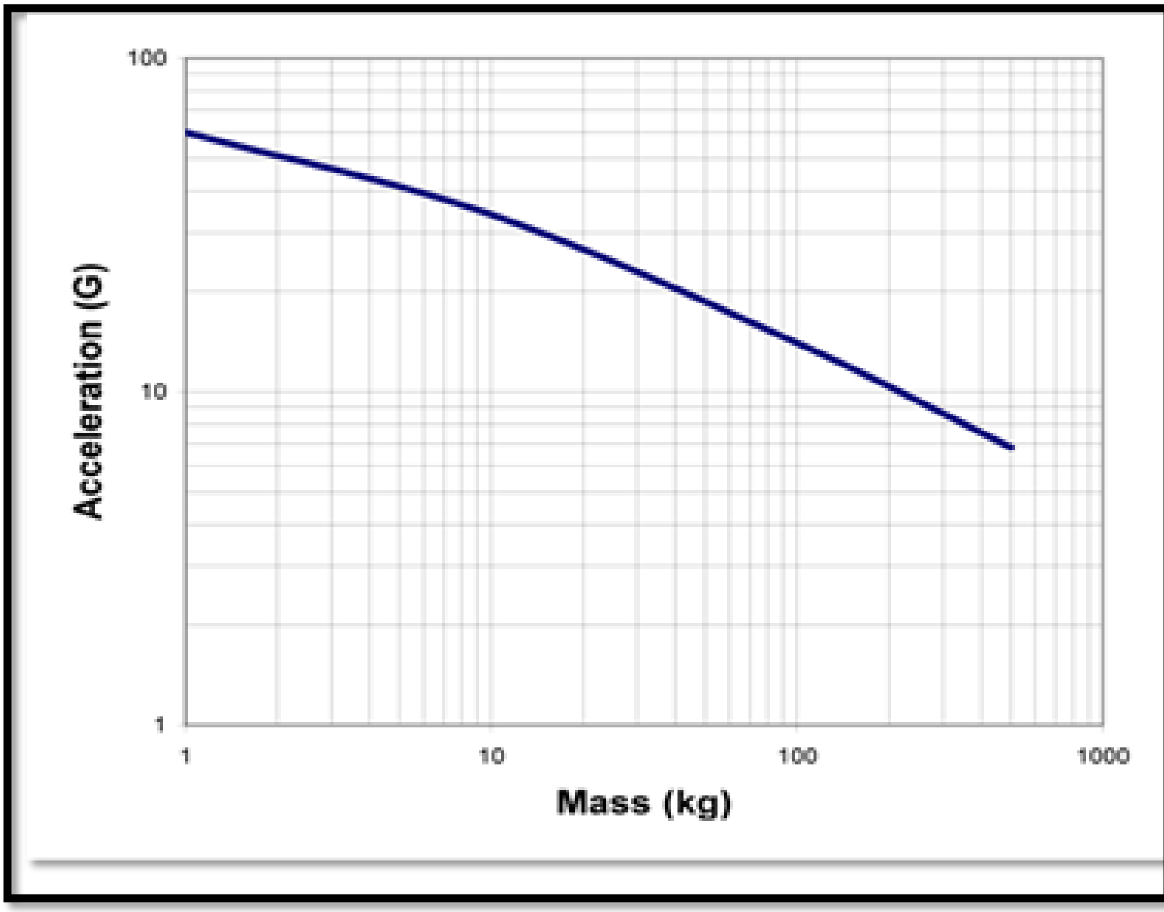
Atlas V Max Acoustic Levels			
Frequency (Hz)	**SLC-41 5-m PLF ***	**SLC-3E 4-m PLF ****	**SLC-41 4-m PLF ****
25	-	116.7	114.0
32	123.0	124.1	118.0
40	124.8	128.5	125.2
50	126.2	124.5	122.5
63	127.5	123.3	121.1
80	128.3	121.7	119.9
100	128.8	121.4	121.4
125	129.0	122.6	122.6
160	128.7	122.9	122.9
200	127.5	122.9	122.9
250	126.0	122.8	122.8
315	124.6	121.9	121.9
400	123.3	121.1	121.1
500	121.9	124.4	124.4
630	120.5	119.0	119.0
800	119.1	119.5	119.5
1000	117.8	116.5	116.5
1250	116.4	114.0	114.0
1600	115.0	112.0	112.0
2000	113.6	110.8	110.8
2500	112.3	109.6	109.6
3150	110.9	108.5	108.5
4000	109.5	107.3	107.3
5000	108.1	106.6	106.6
6300	106.8	106.0	106.0
8000	105.4	105.5	105.5
10000	104.0	105.1	105.1
OASPL (dB)	138.1	135.3	134.1

* - Baseline: 95% probability and 50% confidence assumes 40 to 50% fill by PLF cross-sectional area. dB ref: 20 micropascals
** - Baseline: 95% probability and 50% confidence assumes 50 to 75% fill by PLF cross-sectional area. dB ref: 20 micropascals, applies to all 4-m PLF Configurations (LPF, XPF, XEPF) and all 400 series vehicle configurations (0-3 SRBs)

APPENDIX E. SHOCK



APPENDIX F. MASS ACCELERATION CURVE (MAC)



Preliminary Physical Mass Acceleration Curve (MAC) - ref. NASA-HDBK-7005

1.	Use for appendage mass up to 500 kg only.
2.	Use for appendage frequency less than 80 Hz.
3.	Apply in worst single direction (not necessarily aligned with coordinate direction).
4.	Add a static 1.5 G in the thrust direction.

APPENDIX G. RESOLVE SYSTEM REQUIREMENTS

These requirements apply to the total RESOLVE package, but some could be mitigated by design, packaging, and isolation of various effects for subsystems within the RESOLVE package, such as the LAVA Subsystem that is the focus of this document. System requirements that apply only to the LAVA Subsystem are covered in Section 3.2. These requirements are included to make the vendor aware of the integrated system-level requirements so that design choices that have possible implications for system-level requirements may be identified and mitigated when possible.

G.1 Vibration

G.1.1 The instrument shall be capable of operating within specification after being subjected to a qualification-level random vibration test in accordance with APR 8070.2, Figure 4.3.2.1-1 (included as Appendix A). These spectra shall be applied in each of the three orthogonal axes at the mounting points of the assembly, one minute per axis. This is to be used as the standard random vibration specification until further analysis can be performed, including coupled loads analysis with the launch vehicle. This is to be considered the worst-case scenario until further analysis can provide more accurate levels. Verification by analysis is acceptable.

G.1.2 The instrument shall operate within specification after being subjected to sinusoidal vibration in accordance with the Atlas V Users Guide, March 2010, for axial acceleration. For expendable launch vehicle (ELVs), sine sweep testing is used to simulate low-frequency sine transient vibration and sustained, pogo-like sinusoidal vibration. This is to be considered the worst-case scenario until further analysis can provide more accurate levels. Verification by analysis is acceptable.

G.2 Shock (Goal)

G.2.1 The instrument should operate within specification after being subjected to the shock levels specified in Figure 3.2.4-1, Typical Maximum Atlas Shock Levels – Atlas V Standard Payload Adapters for Type D1666 PLA, in the Atlas V Users Guide, March 2010. The shock should be applied in each of the three orthogonal axes at the mounting points of the instrument. This has sufficient scope to include the expected mechanical shocks that could affect the instrument. This is to be considered the worst-case scenario until further analysis can provide more accurate levels.

G.3 Acoustic (Goal)

G.3.1.1 The instrument should be capable of operating within specification after being subjected to the acoustic spectrum in the Appendix D column labeled “SLC-41 5-m PLF.” The acoustic environment can damage instruments. Large, flat surfaces are most susceptible. Analysis can be used to show that the instrument is not susceptible to the acoustic environment.

G.4 Quasi-Static Structural Design Loads

G.4.1 The instrument shall be capable of operating within specification after being subjected to quasi-static loads as defined in the physical mass acceleration curve (MAC) located in Appendix F of this document. Preliminary sizing of the primary (load-carrying) structure is based on load factors furnished by the launch vehicle organization. These load factors shall be applied at the center of mass and are based on design load databases, analyses of similar payloads, and flight data. The preliminary design of payload hardware or equipment items commonly use load factors obtained from a physical MAC. This is to be considered the worst-case scenario until further analysis can provide more accurate levels. Verification by analysis is acceptable.

G.5 Thermal

G.5.1 The RESOLVE system shall be capable of operating over the temperature range of 100 K to 300 K (–173 °C to 27 °C). Heaters, blankets, etc., may be used to maintain a safe operating temperature for the instrument. Additionally, cooling shall be available if needed. The instrument designer shall determine the cooling needs and verify that they are within the system’s capability. This assumes no operation in the shadowed regions.

G.5.2 The RESOLVE system shall survive exposure to the temperature range of 40 K to 300 K (–233 °C to 27 °C). Heaters, blankets, etc., may be used to maintain a safe operating temperature for the instrument. Additionally, cooling shall be available if needed. The instrument designer shall determine the cooling needs and verify that they are within the system’s capability. This assumes no operation in the shadowed regions. Verification by analysis is acceptable. If requirement is verified by analysis, then thermal models that are compatible with Thermal Desktop, Version 5.4 shall be used.

G.6 Fatigue

G.6.1 Fatigue shall be considered in the design of structural elements. Deleterious residual stresses and stress concentrations shall be avoided or minimized. Special attention shall be given to elements subjected to a large number of cycles at high stress levels. Material selection shall consider fatigue characteristics in relation to the design requirements of the structural element. Fatigue analyses shall be performed for flight structures and a scatter factor of 4. 0 on life at limit load is required. The contractor shall follow the standard design/analysis practice for spaceflight hardware.

G.7 Discontinuities

G.7.1 Sharp discontinuities shall be avoided or minimized in the primary and secondary structure. If applicable, when significant discontinuities exist, increases in local stresses caused by these discontinuities must be accounted for by applying a stress concentration factor. The value of the stress concentration factor shall be determined by analysis, test, or comparison to published data. The contractor shall follow the standard design/analysis practice for spaceflight hardware.

G.8 Residual Stresses

G.8.1 Residual stresses caused by fabrication operations, weld mismatch, assembly, or proof testing shall be evaluated and their effects, where significant, shall be added to the primary stresses. The residual stress distribution of all welds and heat affected zones shall be based on measured values, whenever possible. For pressure vessels, simulated weld specimens with the proper geometric constraints may be used to determine residual stresses. The contractor shall follow the standard design/analysis practice for spaceflight hardware.

G.8.2 Thermal stresses that occur simultaneously with acceleration or applied forces shall be combined in a consistent manner using the appropriate yield and ultimate factors of safety. When qualification/protoflight temperatures are used, the yield factor of safety of 1.0 on the thermal stresses shall be combined with factored loads-induced stresses (1.25 for metallic structures). When qualification/protoflight temperatures are used, the ultimate factor of safety of 1.17 on the thermal stresses shall be combined with factored loads-induced stresses (1.40 for metallic structures, 1.5 for composites). Note that for thermal stresses, the FS is 1.17 for either metallic or composite structures. The contractor shall follow the standard design/analysis practice for spaceflight hardware.

G.9 Stress Analyses

G.9.1 Stress analyses shall be performed on all instrument primary and secondary flight structures. Detailed analyses shall be carried out at the piece part level (including structural interfaces) to facilitate the margin-of-safety assessment. Stress analyses using classical hand analyses and/or finite element modeling shall be performed following acceptable aerospace industry standards. Approaches and results of stress analyses shall be adequately documented for reviews or audits. As a minimum, documentation shall include derivation of loads; modeling assumptions; physical dimensions of parts and material, including bolt sizes; and margins of safety. The contractor shall follow the standard design/analysis practice for spaceflight hardware.

G.10 Outgassing

G.10.1 All materials (including adhesives, coatings, and insulation) shall have a total mass loss (TML) of 1.0% or less and collected volatile condensable materials (CVCM) of 0.10% or less, in accordance with ASTM E595. Outgassing can adversely affect other instruments, as well as contaminate samples to be analyzed by the instrument itself. Assistance can be found at http://outgassing.nasa.gov/. The contractor shall follow the test methods in ASTM E595.

G.11 Torque Margin

G.11.1 The torque margin (TM) requirement defined in GSFC-STD-7000 (GEVS), Section 2.4.5.3, shall apply to all mechanical functions, those driven by motors as well as springs, etc., at beginning of life (BOL). End-of-life (EOL) mechanism performance shall be determined by life testing, and/or by analysis; however, all torque increases resulting from life test results and/or analysis shall be included in the final TM calculation and verification. Margins shall include all flight drive electronics effects and limitations. This torque margin requirement relates to the verification phase of the hardware in question. Conservative decisions should be made during the design phase to ensure adequate margins are realized. However, under some unique circumstances these specified factors of safety (FOS) might be excessive and detrimental to the design of a system. For cases that require approval of a waiver, FOS shall be determined based on design complexity, engineering test data, confidence level, and other pertinent information.

G.12 Fasteners

G.12.1 All threaded fasteners shall employ a locking feature. If not locked in the torqued, preloaded position, threaded fasteners subjected to vibration and thermal cycling loads will tend to relieve their preload and potentially jeopardize the mission.

G.13 Solder Joints

G.13.1 All materials at a solder joint shall be selected to avoid the formation of potentially destructive intermetallic compounds. Solder joints can be significantly weakened by excessive intermetallic formations. Particularly destructive is the formation of gold-tin intermetallics, which are brittle and change the conductivity of the joints. Substrates to be joined using a soldering process should be selected to mitigate the formation of these compounds.

G.14 Solder Joints (Goal)

G.14.1 Solder joints should be designed in accordance with NPD 8730.2C, Attachment A, Criteria to Mitigate Risks Associated with Lead-Free Solder and Surface Finishes. NPD 8730.2C is not applicable to Class D missions, but it is a goal to meet this standard if possible.

G.15 Precision Locating

G.15.1 When precise location of a component is required, the design shall use a stable, positive location system (not relying on friction) as the primary means of attachment. When in the domain of arc-sec to sub-arc-sec location requirements, the use of pinning or a similar non-friction-reliant method will help maintain alignment through all expected stresses.

G.16 EMI

G.16.1 The instrument and subsystems shall comply with EMI/EMC requirements in accordance with Appendix B. Appendix B references APR 8070.2, Table 4.4.2-1 (provided), and shall ensure that the payload will not generate potentially damaging electromagnetic interference and that the instrument will not be susceptible to emissions that could adversely affect its safety and performance. Verification by analysis is acceptable where applicable.

G.17 Materials

G.17.1 Allowable material property data shall be obtained from the approved version of the Metallic Materials Properties Development and Standardization (MMPDS) Handbook, and only Type A-Basis material properties (99% probability of survival with 95% confidence level) or equivalent shall be used for metallic primary structures. This is to ensure the material properties used in the design and analysis of the instrument are correct and the calculated margins of safety will be accurate. MMPDS-06 is the current version (April 2011).

G.18 Pressure Vessels

G.18.1 Pressure vessels shall be designed and qualified in accordance with ANSI/AIAA S-080 (ANSI/AIAA S-081 for COPV). This is the standard design specification for aerospace pressure vessels.

G.19 Printed Circuit Boards (Goal)

G.19.1 All flight printed circuit boards (PCBs) should be verified by coupon testing before assembly of components onto the boards. Verifying the integrity of printed circuit boards reduces the risk of an on-orbit board failure, and saves the added cost of replacing flight-qualified components and reassembly if board failure occurs during qualification testing.

G.20 Electrostatic Discharge (ESD)

G.20.1 All avionics enclosures shall be protected from ESD. All external connectors must be fitted with shorting plugs or appropriate caps during transportation between locations. Additionally, all test points and plugs must be capped or protected from discharge for flight. Capping open connectors provides protection from electrostatic discharge resulting from space charging.

G.21 Tin Whiskers

G.21.1 The use of pure tin, cadmium, and zinc plating in flight and ground electrical hardware shall be prohibited. High-purity tin, zinc, and cadmium finishes are prone to formation of metallic whiskers, which may produce an electrical shorting or contamination hazard. The current worldwide initiative to reduce the use of potentially hazardous materials such as lead (Pb) is driving the electronics industry to consider alternatives to the widely used tin-lead alloys used for plating. Pure tin, cadmium, and zinc finishes renew the concern over the threat of system failures caused by metallic whiskers.

NNK12427240R -- ATTACHMENT C

VDU GC-MS: DELIVERABLE ITEMS LIST AND SCHEDULE (DILS)

29-Feb-12

Item #	Description	Reference	Quantity	Delivery Date
1	Status report by weekly telecon	SOW 2.2.1	95 each	Weekly
2	Written Monthly Status Report	SOW 2.2.2	24 each	Monthly
	Proposed project plan identifying tasks, milestones, and resources needed to meet major milestones	SOW 2.1	1	2 weeks after contract award
3	Updated design phase project plan identifying tasks, milestones, and resources needed to meet major milestones	SOW 2.4.4	1	PDR
4	Mechanical drawings, Pro-E compatible drawings of all components and integrated instrument	SOW 2.8	1	CDR
5	Electrical design drawings	SOW 2.8		CDR
6	Documentation of analysis supporting verification of design requirements to include methodology/process and data/results	SOW 3.2-3.5	1	NLT 7/15/13
7	A complete Bill of Materials of all components specified in the design of the system. As a minimum, the Bill of Materials shall provide the item description, manufacturer's part number, lead time for procurement, supplier, supplier's part number, and component designator (if	SOW 2.5.1	1	NLT 7/15/13
8	Final report to include design choices, justification for design choices, data collected during testing/evaluation of components, and options considered during the design phase	SOW 2.4.3.2	1	CDR
9	Preliminary Design Review Presentation Package	SOW 2.4.1.2	1	7 days before PDR
10	Preferred system solutions including major tradeoffs and options	SOW 2.4.1.2	1	PDR
11	Preliminary functional baseline with trade off analysis	SOW 2.4.1.2	1	PDR
12	Preliminary system software functional requirements	SOW 2.4.1.2		PDR
13	Preliminary risk assessment/mitigation plan and safety analysis	SOW 2.4.1.2	1	PDR
14	Preliminary test plan for validation and verification of all technical requirements (Section 3.2) for LAVA GC-MS	SOW 2.4.1.2	1	PDR
15	Preliminary interface control document	SOW 2.4.1.2	1	PDR
16	Updated schedule data	SOW 2.4.1.2	1	PDR
17	Preliminary limited life items list	SOW 2.4.1.2	1	PDR
18	Preliminary subsystem design specifications for hardware and software	SOW 2.4.1.2	1	PDR
19	Preliminary mass and power estimates to include basis of estimation (includes a comparison of estimates to requirements and plan to control growth and meet requirements and design matures)	SOW 2.4.1.2	1	PDR
20	Preliminary technical plan for high and low level water detection, testing, and optimization of system for water analysis	SOW 2.4.1.2	1	PDR
21	Preliminary technical plan for volatile components specified in the technical requirements (Section 3.2) for LAVA GC-MS	SOW 2.4.1.2	1	PDR

22	updated design phase project schedule that includes milestone charts depicting critical paths and indicating critical dates in the project	SOW 2.4.1.2	1	PDR
23	Preliminary Design Review Report	SOW 2.4.1.1	1	7 days after PDR
24	Continuation Review Package	SOW 2.4.2	1	7 days before CR
25	Updated documentation from 30% Design Review/PDR (1a – l). Documents shall be presented for approval and baselined.	SOW 2.4.2		CR - NLT 9/15/12
26	Validation and verification plan (1e) to address all requirements in design phase of project, designating the method of verification (test, analysis, design)	SOW 2.4.2	1	CR - NLT 9/15/12
27	Testing data to support design choices and trade-offs	SOW 2.4.2		CR - NLT 9/15/12
28	Operational concept detailed to support analysis modes defined in the technical requirements (Section 3.2) for LAVA GC-MS	SOW 2.4.2	1	CR - NLT 9/15/12
29	Preliminary user interface description	SOW 2.4.2	1	CR - NLT 9/15/12
30	Demonstrated GC-MS sampling rate to obtain a full mass spectrum for 1 Th to 65 Th at greater than or equal to 6 Hz	SOW 2.4.2		CR - NLT 9/15/12
31	Continuation Review Report	SOW 2.4.2	1	7 day after CR
32	CDR Presentation Package	SOW 2.4.3.2	1	7 days before CDR
33	Updated functional baseline with trade-off analysis	SOW 2.4.3.2	1	CDR
34	Updated system software functional requirements	SOW 2.4.3.2		CDR
35	Updated risk assessment/mitigation plan and safety analysis	SOW 2.4.3.2	1	CDR
36	Updated test plan for validation and verification of all technical re-quirements listed in Section 3.2 for LAVA GC-MS	SOW 2.4.3.2	1	CDR
37	Updated interface control document	SOW 2.4.3.2	1	CDR
38	Updated project schedule data	SOW 2.4.3.2	14 EA	CDR
39	Updated limited life items list	SOW 2.4.3.2	1	CDR
40	Updated subsystem design specifications for hardware and software	SOW 2.4.3.2	1	CDR
41	Updated mass and power estimates to include the basis of estima-tion	SOW 2.4.3.2	1	CDR
42	Updated technical plan for high-level and low-level water detection, testing, and optimization of the system for water vapor analysis	SOW 2.4.3.2	1	CDR
43	Updated technical plan for detection of volatile components speci-fied in the requirements (Section 3.2)	SOW 2.4.3.2	1	CDR
44	Demonstration of water detection range and reproducibility on a GC system representative of the contractor’s technical approach, including all materials planned for use in the system from injection to detection. Generation of known water concentrations should use a laboratory standard generator or standard salt bath solutions.	SOW 2.4.3.2		CDR
45	Demonstration of permanent gas separations, including hydro-gen/helium separation and thermal conductivity detector (TCD) detection limits for all vapors	SOW 2.4.3.2		CDR
46	Test/analysis/design data to support validation and verification of all technical requirements defined in Section 3.2 for LAVA GC-MS	SOW 2.4.3.2		CDR
47	Software DDS Interface Definition Language Documentation	SOW 2.4.3.2	1	CDR

48	Preliminary programmers guide to DDS interface	SOW 2.4.3.2	1	CDR
49	Report on main-board computer that will be used to run DDS interface	SOW 2.4.3.2	1	CDR
50	Electrical drawings, schematics, and connector pinout, assembly and electrical interface drawings (board level schematics available on request)	SOW 2.4.3.2		CDR
51	Validation and verification plan for hardware checkout	SOW 2.4.3.2	1	CDR
52	Updated project cost estimates for deliverables in Fabrication Phase	SOW 2.4.3.2	1	CDR
53	Critical Design Review Report	SOW 2.4.3.2	1	7 days after CDR
54	*Updated* fabrication phase project schedule that includes milestone charts depicting critical paths and indicating critical dates in the project	SOW 2.13	*1*	CDR
55	Data delivery package	SOW 2.5.1	1	NLT 7/15/13
56	Full drawing package of "as-built" system, to include a full drawing package of electronics, drawing package of mechanical components, owner's manuals for OEM items, parts list for all components including part number, manufacturer in-formation, and data sheets	SOW 2.5.1	1	1 month after fab complete per project schedule
57	One to three functional GC-MS systems built to design specifications	SOW 2.5.1		NLT 7/15/13
58	Test plans and data taken during build and checkout of the system to include GC chromatograms and MS scans of sample mixtures to demonstrate the system's ability to meet requirements	SOW 2.5.1		NLT 7/15/13
59	Safety documentation The contractor **shall** perform any safety related analyses necessary to support the safety requirements of Section 4.2. The results of these analyses **shall** be summarized in a Contractor format Safety Analysis Report that will be provided to the NASA/KSC COTR for review.	SOW 2.5.1	1	NLT 7/15/13
60	Operator's manual, to include instructions for warm-up, calibration, operation, troubleshooting, and shutdown	SOW 2.5.1	1	NLT 7/15/13
61	Maintenance manual, to include instructions for replacement of components with an operational limited lifetime (less than 2 years)	SOW 2.5.1	1	NLT 7/15/13
62				
63	Long lead items list to include estimated lead time and vendor quotes for components with an estimated lead time over 3 months	SOW 2.5.1	1	
64	Interface Control Document	SOW 2.10	1	CDR
65	interface drawing package	SOW 2.9	1	CDR
66	Models used in the design analysis and performance of the below analyses or used for CAD/CAM/CAE in a file format compatible with CREO/Pro-E Wildfire 5	SOW 2.9		NLT 7/15/13
67	Communication and Control Specification Document (CCSD)	SOW 2.10	1	NLT 7/15/13
68	Structural Analyses Report	SOW 2.12	1	NLT 7/15/13
69	Fabrication, Assembly, and Inspection Flow plan	SOW 2.5.2	1	CDR
70	Spare thermal conductivity detectors	SOW 2.14	2 for each instrument	NLT 7/15/13
71	1,000 centimeters of each type wire it has used in fabricating the GC-MS	SOW 2.14	1000 cm of each wire type	NLT 7/15/13

72	Spare mass spectrometer detectors for each GC-MS instrument	SOW 2.14	2 for each instrument	NLT 7/15/13
73	ionization sources for each source installed in the GC-MS instrument	SOW 2.14	2 for each instrument	NLT 7/15/13
74	Spare connectors, pins, and sockets	SOW 2.14	1 complete set	NLT 7/15/13
	spare gas chromatography column	SOW 2.14	1 for each installed in instrument	NLT 7/15/13
	Spare high voltage power supply	SOW 2.14	1 for each instrument	NLT 7/15/13
75	Other parts the vendor deems necessary to repair the GC-MS instrument	SOW 2.14	ea	NLT 7/15/13
76	GC-MS Test Plan for the verification tests	SOW 2.4.3.2; 3.2	1	CDR
77	Verification Test Procedures	SOW 3.3		1 month prior to testing
78	Verification Test Reports	SOW 3.5		2 weeks after testing is performed
79	Quality Management System Plan	SOW 4.1.1	1	PDR
80	Schedule / Inspection Control Point Outline (ICPO)	SOW 4.7.1	1	CDR
81	Acceptance Data Package	SOW 4.7.4	3	NLT 7/15/13
82	Verification matrix	SOW 3.1	1	CDR
83	Test Printed Wiring Board (PWB) coupons	SOW 4.8.1		When procured as specified in project plan
84	A preliminary Bill of Materials of all components specified in the design of the sys-tem. As a minimum, the Bill of Materials shall provide the item description, man-ufacturer's part number, lead time for procurement, supplier, supplier's part num-ber, and component designator (if applicable).	SOW 2.4.3.2	1	CDR

IAC-11-A5.1.4

RESOLVE

Ground Truth for Polar Volatiles as a Resource

William E. Larson
NASA-Kennedy Space Center

Martin Picard
Canadian Space Agency

Anthony Colaprete
NASA- Ames Research Center

Gerald B. Sanders
NASA- Johnson Space Center

Richard C. Elphic
NASA- Ames Research Center

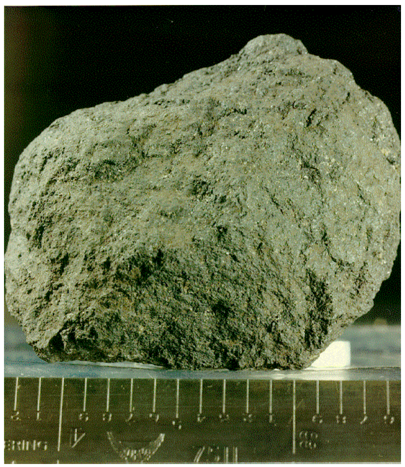
62nd International Astronautical Congress
Cape Town, South Africa
October 2011

william.e.larson@nasa.gov

Our Evolving Understanding of the Moon and its Resources

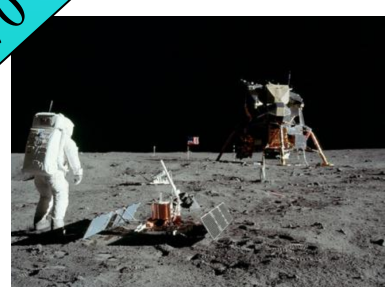
RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

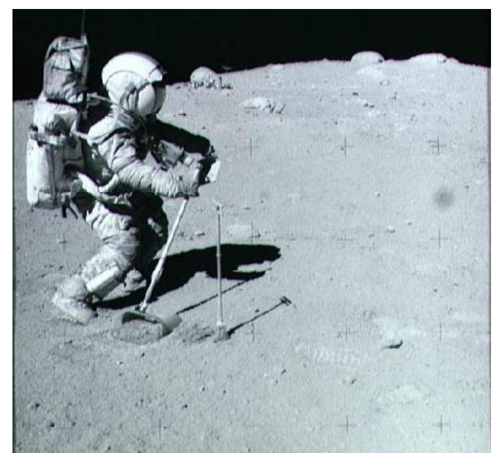
1961: 1970 1994 1998 2008 2009 2010



Apollo samples, 1969-1972 point to a bone dry Moon

In a 1961 paper, Watson, Murray and Brown theorize that cold traps at the moon's poles may contain water ice





Our Evolving Understanding of the Moon and it's Resources

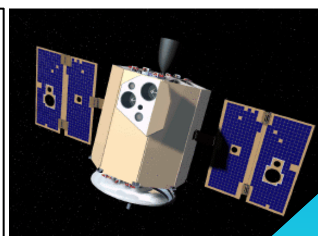
RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

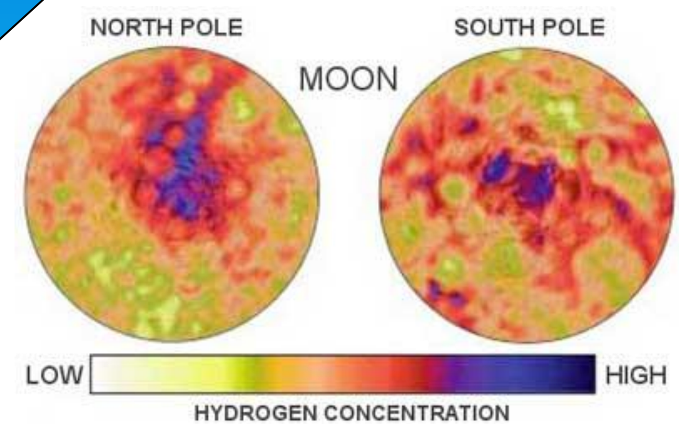
Missions to the Moon in the 1990's provided intriguing data that suggested the permanently shadowed regions of the Moon may harbor water ice and other volatiles

1961: 1970 1994 1998 2008 2009 2010

Watson, Murray and Brown theorize that cold traps at the moon's poles may contain water ice

Clementine Bi-Static Radar suggest Water Ice in permanently shadowed regions near the poles





Neutron Spectrometer aboard Lunar Prospector detects elevated levels of hydrogen that correlates with permanent shadow

Our Evolving Understanding of the Moon and its Resources

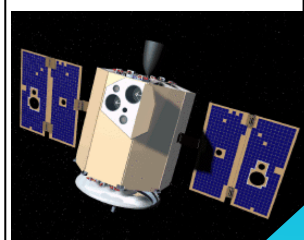
RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

Conclusions drawn from Clementine and Lunar Prospector regarding lunar water ice was vigorously debated.

1961: 1970 1994 1998 2008 2009 2010

Watson, Murray and Brown theorize that cold traps at the moon's poles may contain water ice

Clementine Bi-Static Radar suggest Water Ice in permanently shadowed regions near the poles



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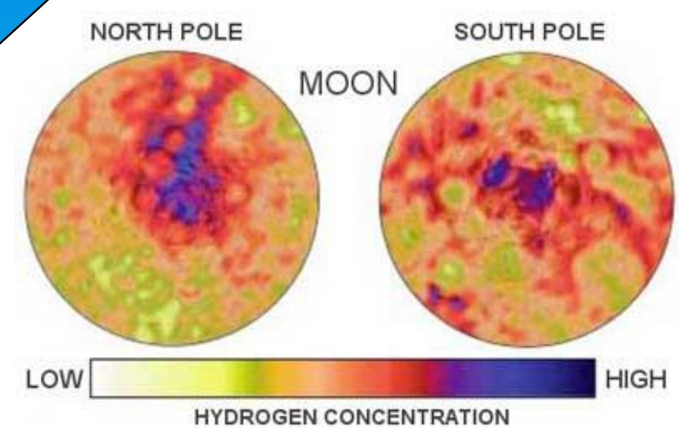

Planetary Scientist, Larry Taylor, says he will "eat his shorts if there is water on the moon."

Our Evolving Understanding of the Moon and its Resources

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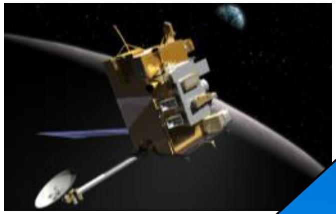
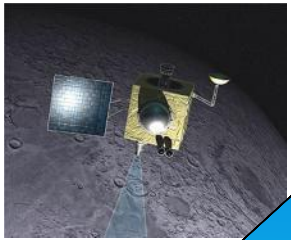
Integrated data sets from instruments on LRO support the existence of large quantities of water ice in the PSRs and in partially sunlit regions



Synthetic Aperture Radar on Chandrayaan 1 returns data that is consistent with water ice in the PSR's



LCROSS impacts Cabeus A and clearly detects significant quantities of water in the ejecta

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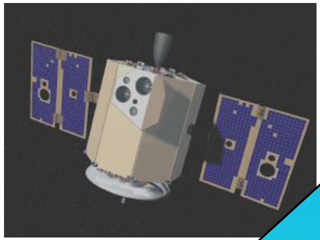

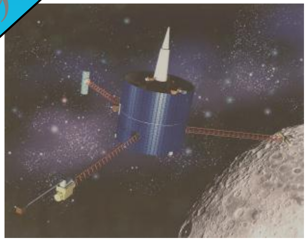

Neutron Spectrometer aboard Lunar Prospector detects elevated levels of hydrogen that correlates with permanent shadow

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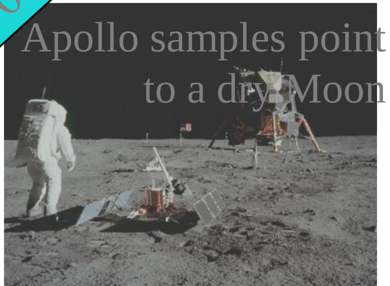
Apollo samples point to a dry Moon



1961: 1970 1994 1998 2008 2009 2010

LCROSS & LRO Definitively Prove Existence of Volatiles at the Lunar Poles

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

					Instrument			
	Column Density (# m^{-2})	Relative to H2O(g) (NIR spec only)	Concentration (%)	Long-term Vacuum Stability Temp (K)	UV/Vis	NIR	LAMP	M3
CO	1.7e13±1.5e11		5.7	15			x	
H_2O(g)	5.1(1.4)E19	1	5.50	106		x		
H_2	5.8e13±1.0e11		1.39	10			x	
H_2S	8.5(0.9)E18	0.1675	0.92	47	x	x		
Ca	3.3e12±1.3e10		0.79				x	
Hg	5.0e11±2.9e8		0.48	135			x	
NH_3	3.1(1.5)E18	0.0603	0.33	63		x		
Mg	1.3e12±5.3e9		0.19				x	
SO_2	1.6(0.4)E18	0.0319	0.18	58		x		
C_2H_4	1.6(1.7)E18	0.0312	0.17	~50		x		
CO_2	1.1(1.0)E18	0.0217	0.12	50	x	x		
CH_3OH	7.8(42)E17	0.0155	0.09	86		x		
CH_4	3.3(3.0)E17	0.0065	0.04	19		x		
OH	1.7(0.4)E16	0.0003	0.002	>300 K if adsorbed	x	x		x
H_2O (adsorb)			0.001-0.002					x
Na		1-2 kg		197	x			
CS					x			
CN					x			
NHCN					x			
NH					x			
NH_2					x			

Volatiles comprise possibly 15% (or more) of LCROSS impact site regolith

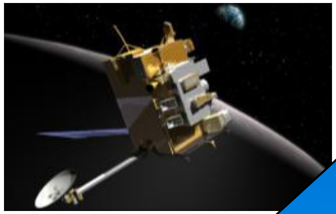
Our Evolving Understanding of the Moon and it's Resouces

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

Larry Taylor is served a cake decorated as a pair of shorts at a Lunar Planetary Institute meeting

1961: 1970 1994 1998 2008 2009 2010

Integrated data sets from instruments on LRO support the existence of large quantities of water ice in the PSRs and in partially sunlit regions



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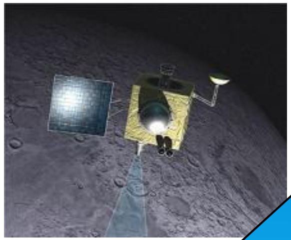

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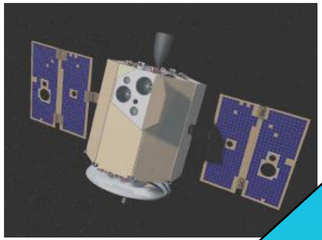

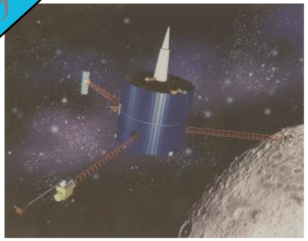

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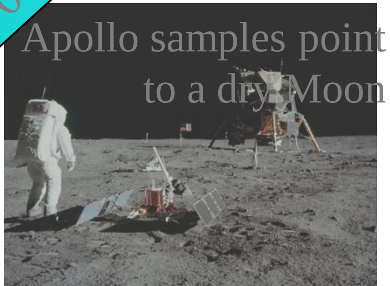
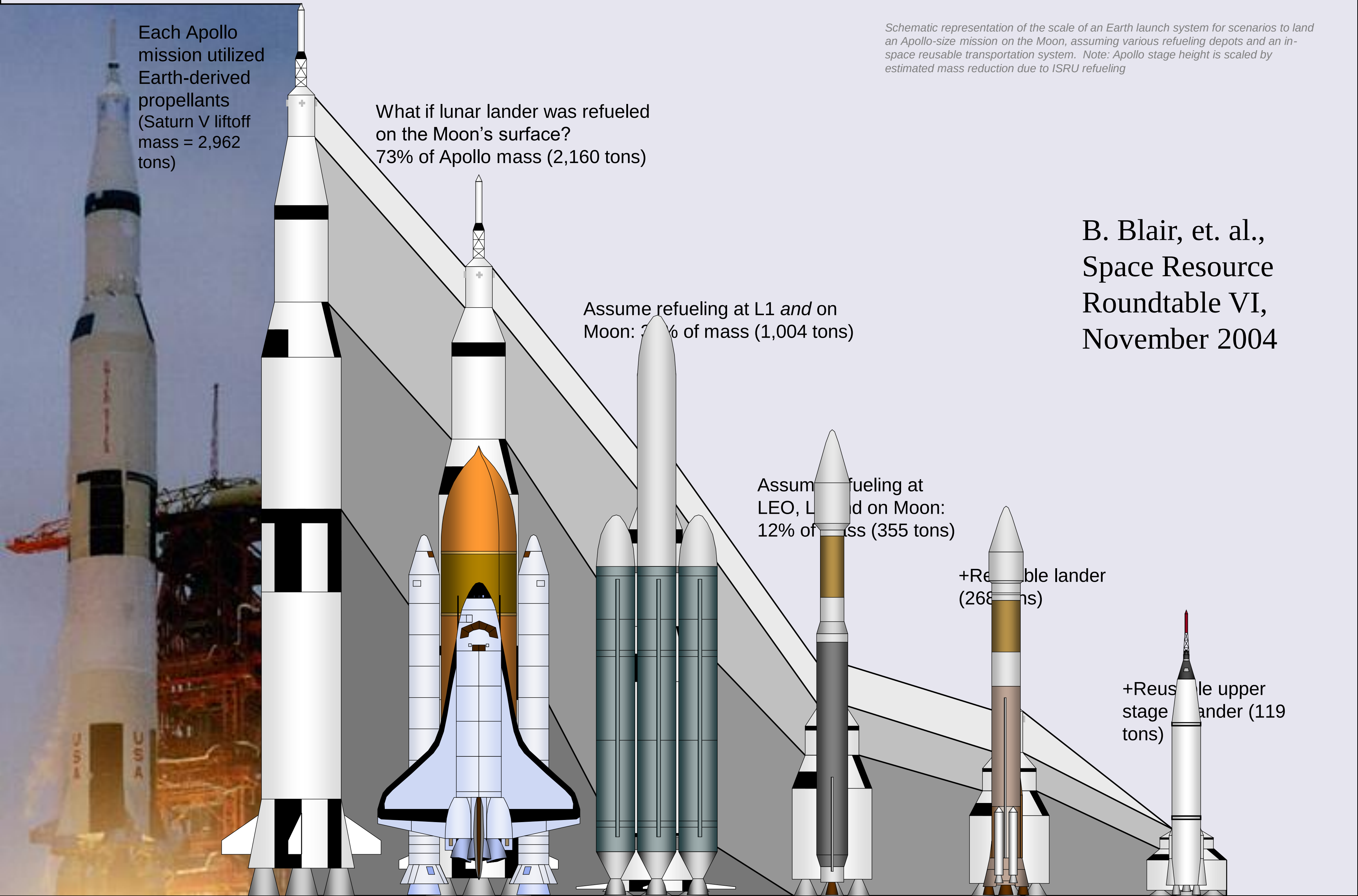


Apollo samples point to a dry Moon

Importance of Lunar Volatiles as a Resource

- Water is Life
  - Oxygen to breath
  - Water to drink
  - Water for cooling systems
  - Water for radiation shielding
  - Water for plants
- Volatiles can be used to manufacture propellant
  - Water is an easy form for the transportation of hydrogen & oxygen
  - Water can be converted into hydrogen and oxygen using abundant solar power in orbit
  - Hydrogen & Oxygen can be liquefied in space and stored in propellant depot
  - Orbital depots open up a commercial market for propellants
  - Alternatively, the hydrogen from the water can be combined with plentiful carbon monoxide to make methane, another useful propellant.
- Harvesting resources at our destinations can dramatically change the our mission architectures.

Propellant from the Moon will revolutionize our current space transportation approach



Schematic representation of the scale of an Earth launch system for scenarios to land an Apollo-size mission on the Moon, assuming various refueling depots and an in-space reusable transportation system. Note: Apollo stage height is scaled by estimated mass reduction due to ISRU refueling

B. Blair, et. al., Space Resource Roundtable VI, November 2004

What's the Next Step?

- We now know with certainty that there are volatiles at one spot on the moon.
- Comparison's of orbital instrument data with the LCROSS plume seem to suggest that the water is not evenly distributed.
- Until we know the distribution and accessibility of the volatiles don't really know if we have a usable resource.
- A "Ground Truth" surface mission is the next logical step.
- RESOLVE is the payload that NASA and the CSA are designing to answer these questions

Surface Mission Drivers

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

- **Given:** **There are potentially substantial hydrogen rich resources on the Moon…**
- **Then:** **We must gain the necessary knowledge to guide future mission architectures to allow effective utilization of in-situ resources to their fullest extent and optimum benefit.**

- **Understand the resources**
  - What resources are there?
  - How abundant is each resource?
  - What are the horizontal and vertical distributions and hetero/homogeneity?
  - How much energy is required to locate, acquire and evolve/separate the resources?

- **Understand environment impact on extraction and processing hardware**
  - What is the local temperature, illumination, radiation environment?
  - What are the physical/mineralogical properties of the local regolith?
  - Are there extant volatiles that are detrimental to processing hardware or humans?
  - What is the impact of significant mechanical activities on the environment?

- **Design and utilize hardware to the maximum extent practical that has applicability to follow-on ISRU missions**
  - Can we effectively separate and capture volatiles of interest?
  - Can we execute repeated processing cycles (reusable chamber seals, tolerance to thermal cycles)?

RESOLVE Mission Requirements

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

Primary Mission:

✓ **Verify the existence of and characterize the constituents and distribution of water and other volatiles in lunar polar surface materials**

- **Map the surface distribution of hydrogen rich materials** (Neutron Spectrometer, Near-IR Spectrometer)
- Extract 1m core sample with minimal loss of volatilesfrom selected sites (Drill /AugerSubsystem)
  - to a depth of 1m
- **Heat multiple samples from each core to drive off volatiles for analysis** (OVEN Subsystem)
  - from 100°K to 473°K
  - from 0 up to 100 psia (reliably seal in aggressively abrasive lunar environment)
- **Determine the constituents and quantities of the volatiles extracted** (LAVA Subsystem)
  - Hope to find and quantify H_2, He, CO, CO_2, CH_4, H_2O, N_2, NH_3, H_2S, SO_2
  - Survive limited exposure to HF, HCl, and Hg

Secondary Mission:

✓ **Demonstrate the ISRU Hydrogen Reduction Process to extract oxygen from lunar regolith**

- **Heat sample to reaction temperature** (OVEN Subsystem)
  - from 473°K to 1173°K
- **Flow H_2 through regolith to extract oxygen in the form of water** (OVEN Subsystem)
- **Capture, quantify, and display the water generated** (LAVA Subsystem)

Major RESOLVE Subsystems

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

- The **Neutron Spectrometer Subsystem** will be used to verify the presence of hydrogen rich materials and then map the distribution of these materials to assist in sample site selection and better understand the morphology of the resource. The Near Infrared (NIR) Spectrometer instrument will be used to scan the immediate vicinity of the drill site before and during drill/auger operations to look for near real-time changes in the properties of the materials exposed during the drilling process.

- The **Near Infrared (NIR) Spectrometer Subsystem** will be used to provide an additional means of surveying the surface and immediate excavation site for water and other volatiles. Provides surface and regolith mineral context. The Near Infrared (NIR) Spectrometer instrument will be used to scan the immediate vicinity of the drill site before and during drill/auger operations to look for near real-time changes in the properties of the materials exposed during the drilling process.

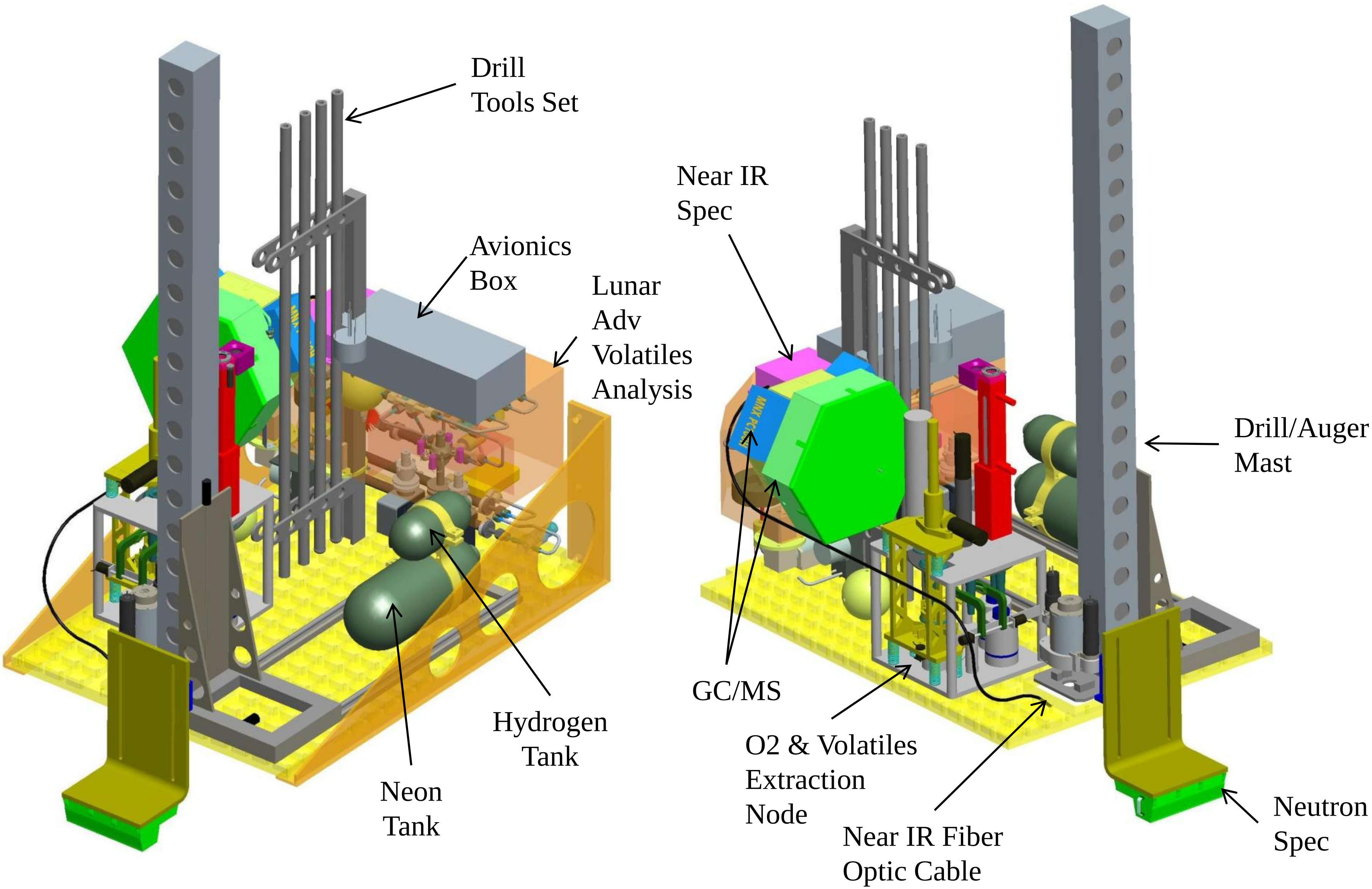
- The **Drill Subsystem** includes the hardware to physically excavate/extract regolith from the lunar surface to a depth of 1 m and perform any type of preparation necessary (grinding, crushing, sieving, etc.) before delivering the sample to one or more reactor chambers for further processing by the Reactor Subsystem. This subsystem will be provided by the Canadian Space Agency (CSA) through a partnering agreement and integrated into the RESOLVE. The excavation device will be instrumented to measure forces/displacements etc. to determine critical bulk properties of the regolith.

- The **O**xygen and **V**olatile **E**xtraction **N**ode **(OVEN)** Subsystem will accept samples from the Drill Subsystem and will evolve the volatiles contained in the sample by heating the regolith in a sealed chamber and will also extract oxygen from the remaining regolith sample. Each sample will be sealed in the OVEN chamber and heated up to 150°C to evolve volatiles (H_20, CO, etc.). At most 1 (one) sample from each core will continue to be heated up to ~900°C and be subjected to hydrogen reduction processing

- The **Lunar Advanced Volatile Analysis (LAVA) Subsystem** will accept the effluent gas/vapor from the OVEN Subsystem and analyze that effluent gas using gas chromatograph and/or mass spectrometer sensor technologies. LAVA Subsystem will design, develop, test, and provide all of the fluid system hardware necessary to support OVEN Subsystem and LAVA Subsystem instrumentation operations. The system will measure constituents below atomic number 70 (including H_2, He, CO, CO_2, CH_4, H_2O, N_2, NH_3, H_2S, SO_2, etc.).

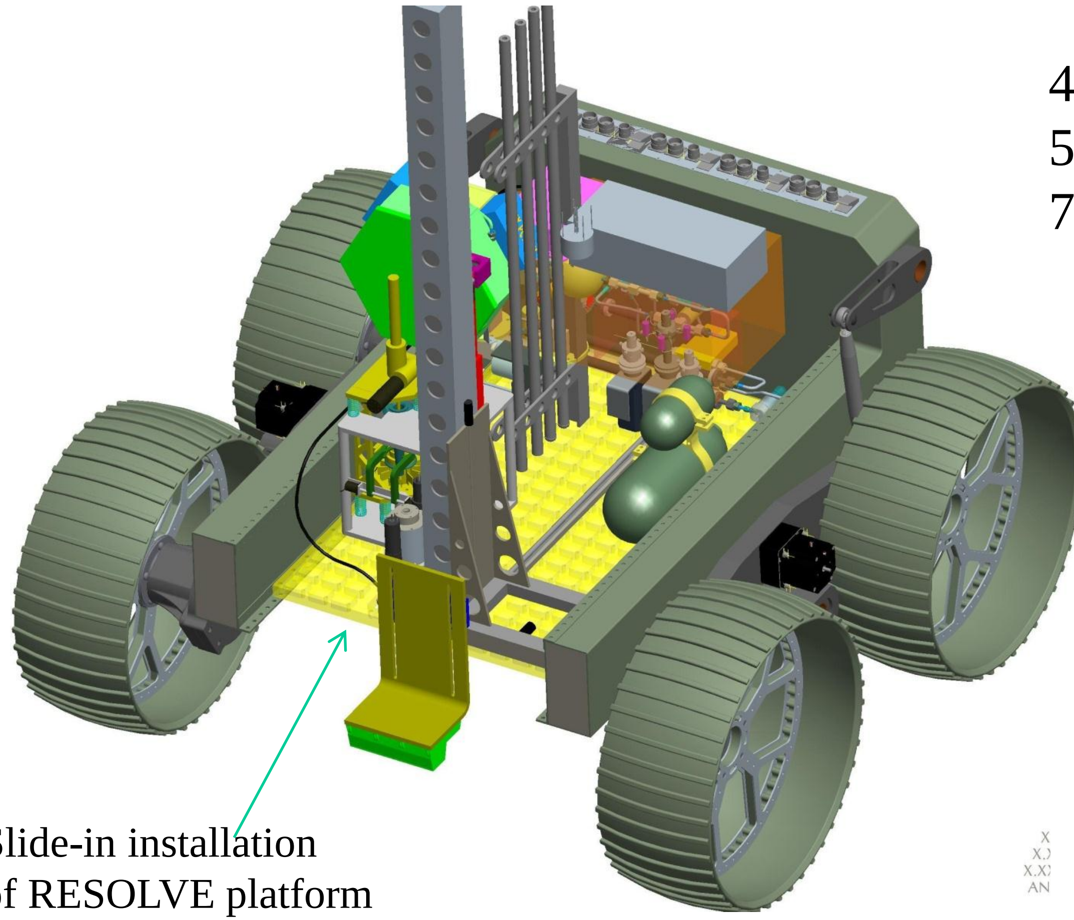
RESOLVE Payload Layout

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction



RESOLVE Integrated with CSA Rover

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction



470mm Length
533mm Width
746mm Height

Slide-in installation
of RESOLVE platform
To CSA Rover

Planning the Mission: Where should we land?

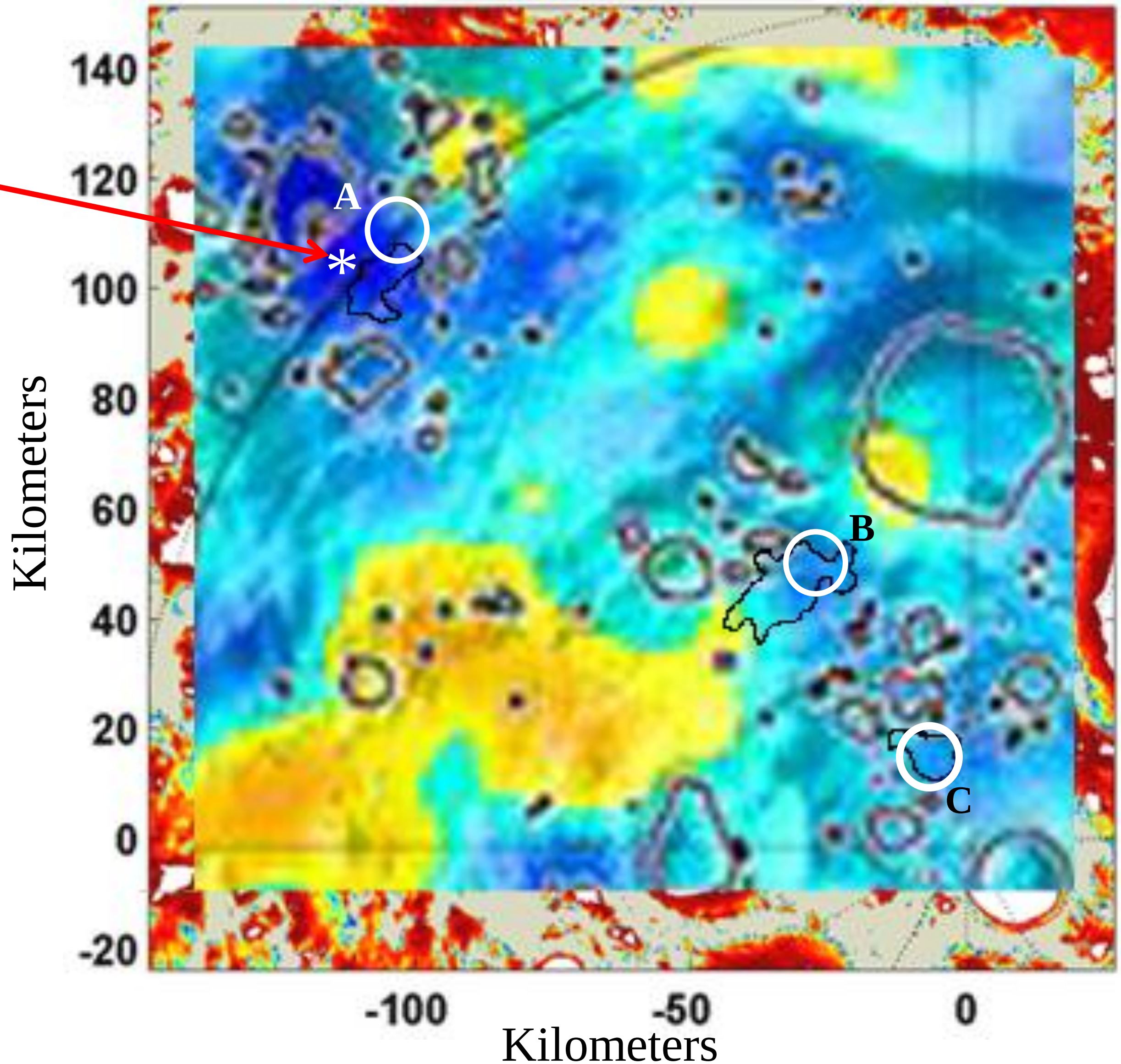
- Permanent Shadowed Craters?
  - LRO radar data suggests large, thick deposits of water ice in some of the Permanently Shadowed Craters
  - However, temperatures are extremely low (<40K), and a mission of any significant duration would probably require a nuclear energy source.
    - Mission would be prohibitively expensive for our current budget environment.
- Partially sunlit regions?
  - Lunar Exploration Neutron Detector (LEND) suggests that there are areas of neutron suppression (indicator of hydrogen) outside of the permanently shadowed regions.
  - David Paige and the DIVINER radiometer team published results indicating that there are many areas in the polar regions that have subsurface temperatures (<100K) that would support the existence of water ice.
  - Solar powered missions are more affordable and the operating environment for hardware is much less harsh.
  - Perhaps a location like this would make it easier to set up a future mining operation on the Moon if the resources were plentiful enough.

RESOLVE Mission Options – Potential South Pole Landing Sites

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

Neutron Depletion

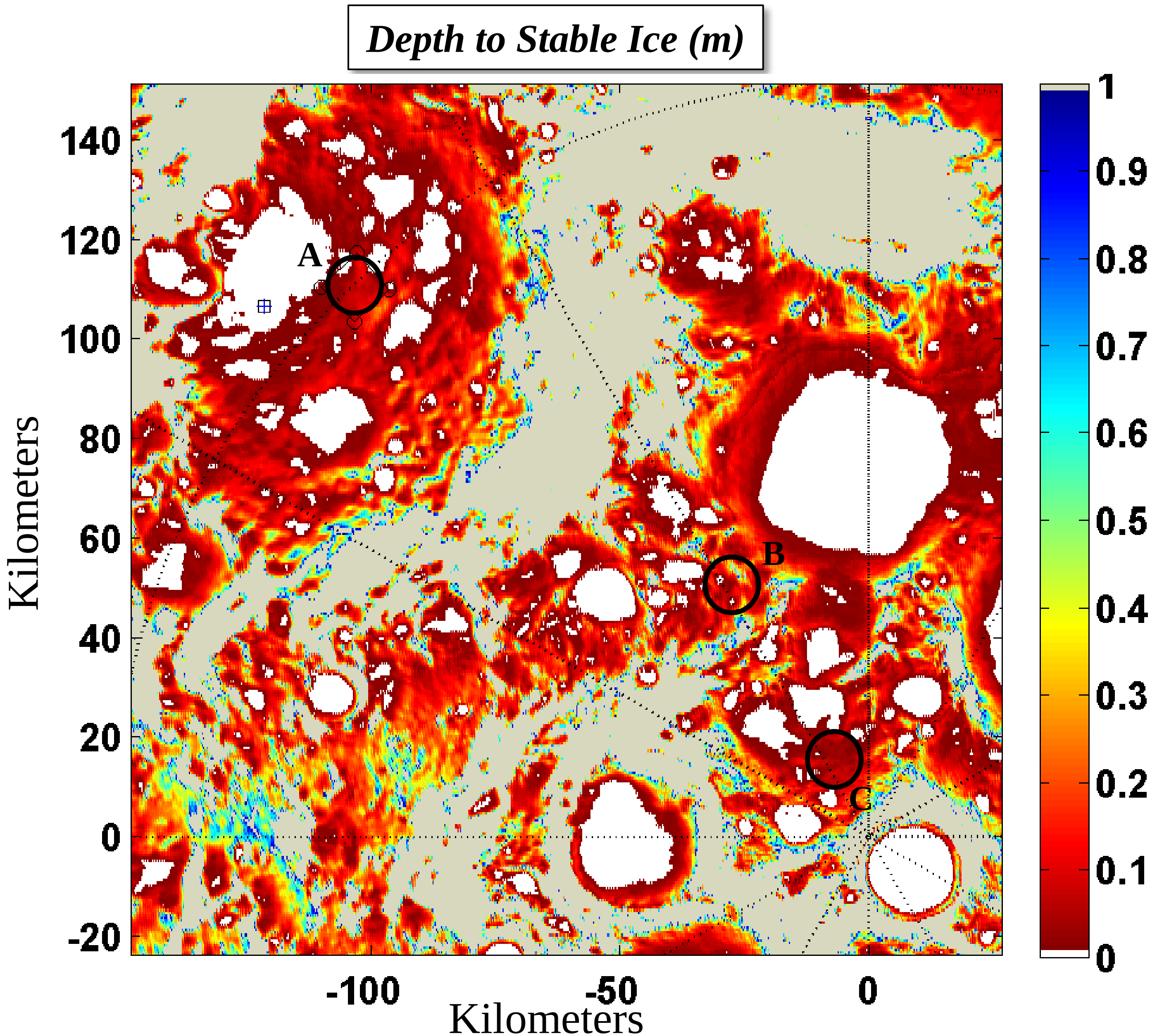
LCROSS impact site



Dark blue represent the areas of highest neutron suppression

Circles A, B & C selected for closer examination

RESOLVE Mission Options – Potential South Pole Landing Sites



RESOLVE Mission Options – Potential South Pole Landing Sites

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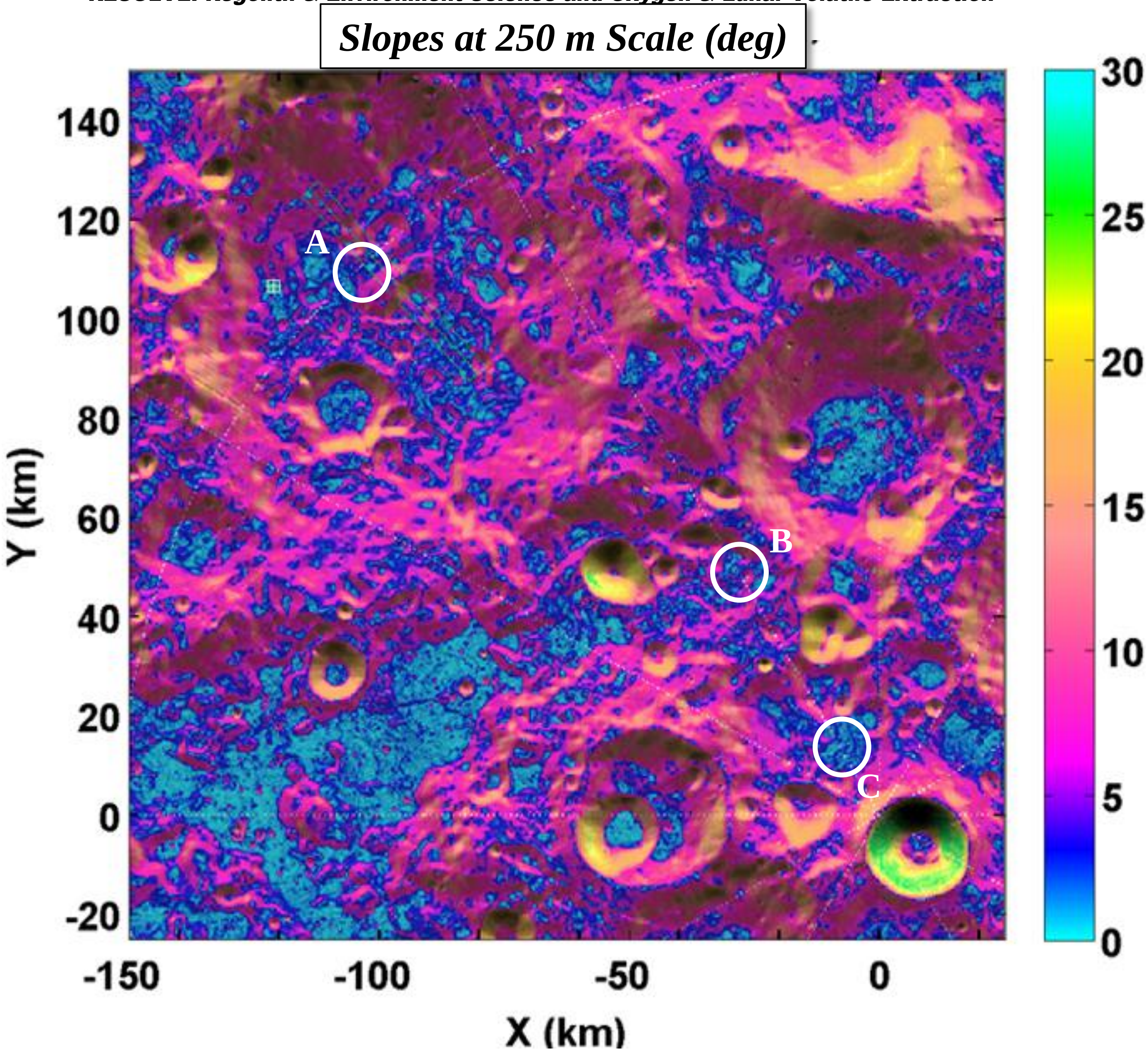
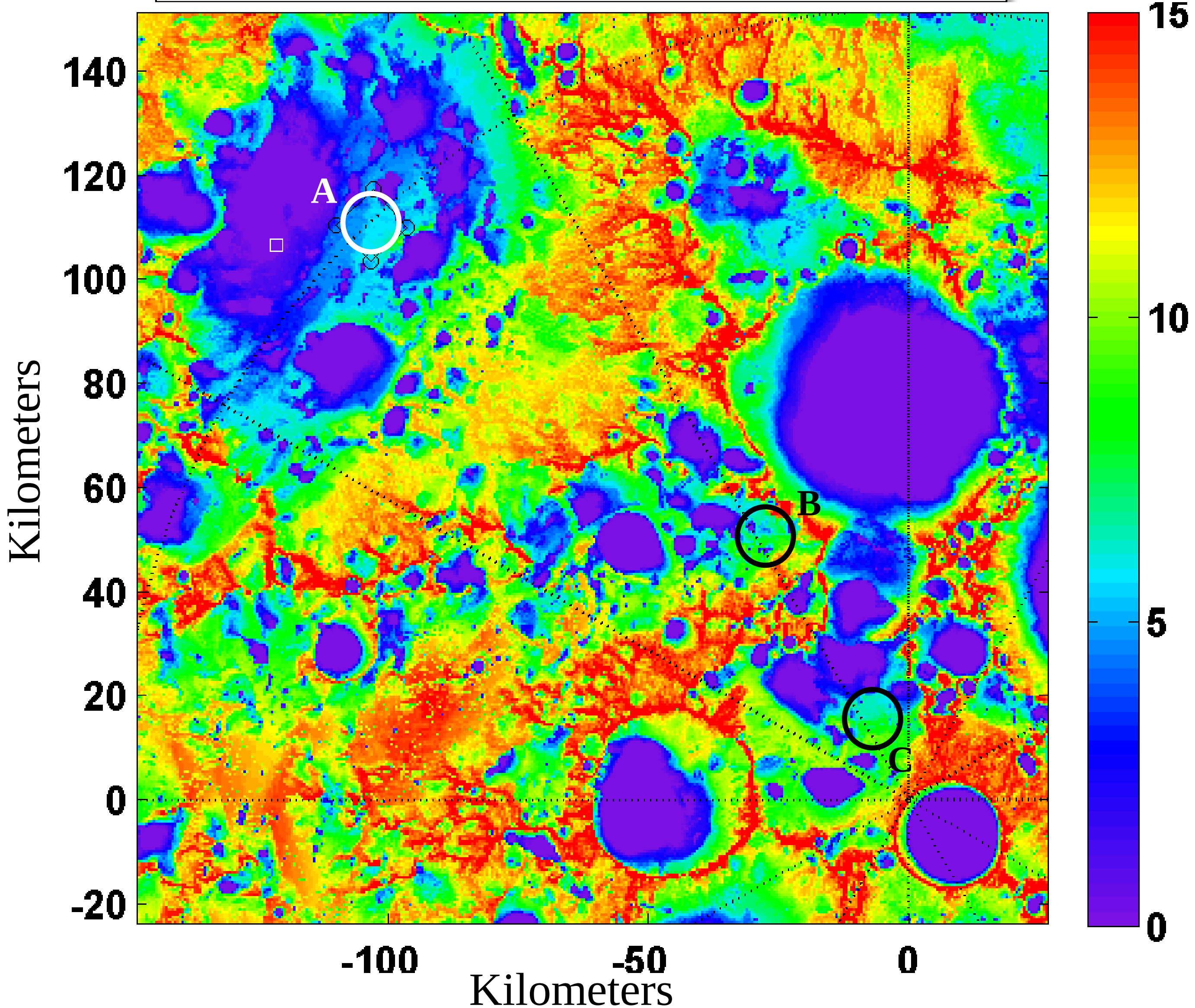


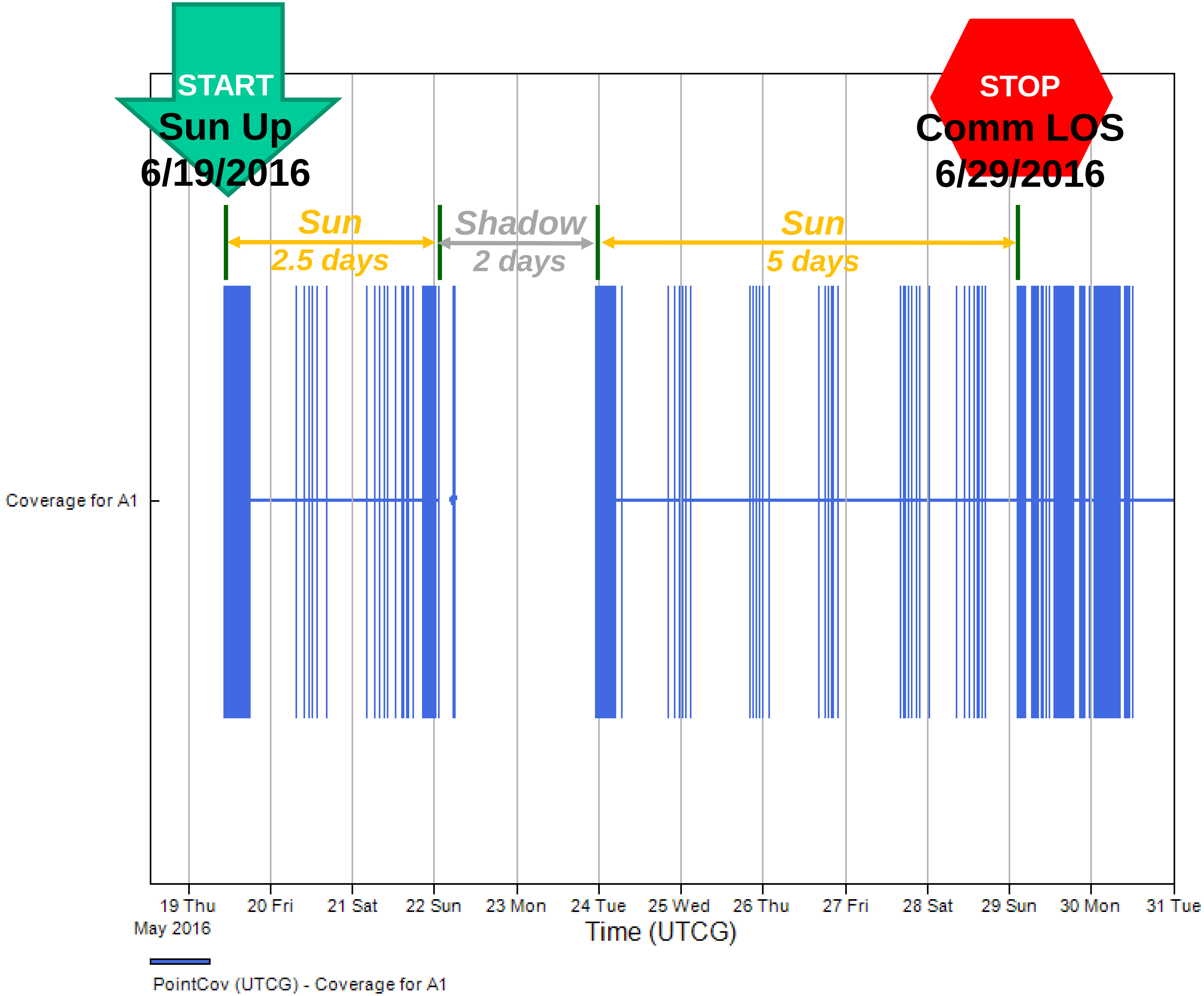
RESOLVE Mission Options – Potential South Pole Landing Sites

Maximum Days of Sunlight Using LOLA DEM



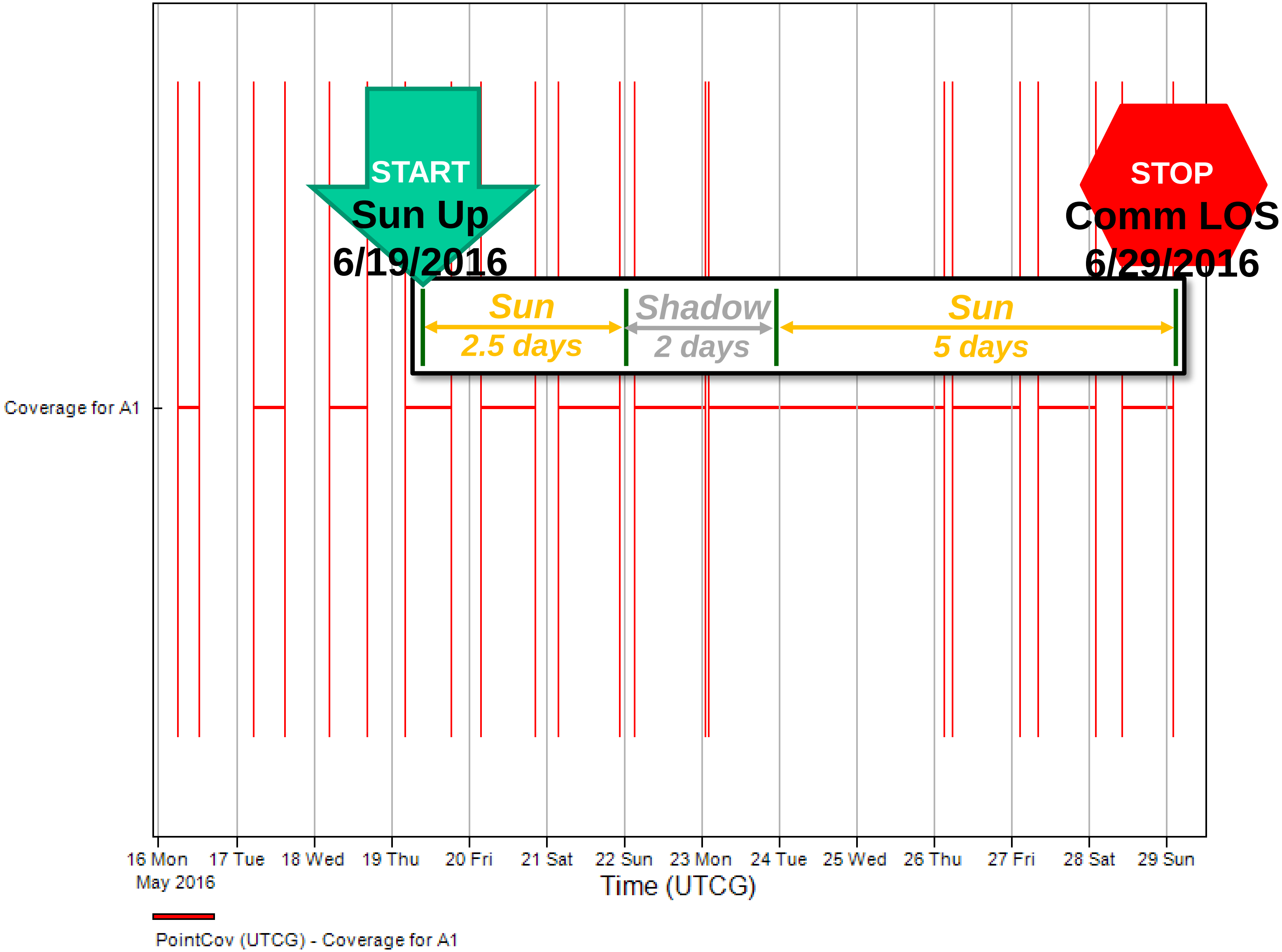
Sunlight Availability
(Cabeus Site A1, May 2016)

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction



Communications Availability
(DTE McMurdo, Cabeus Site A1, May 2016)

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction



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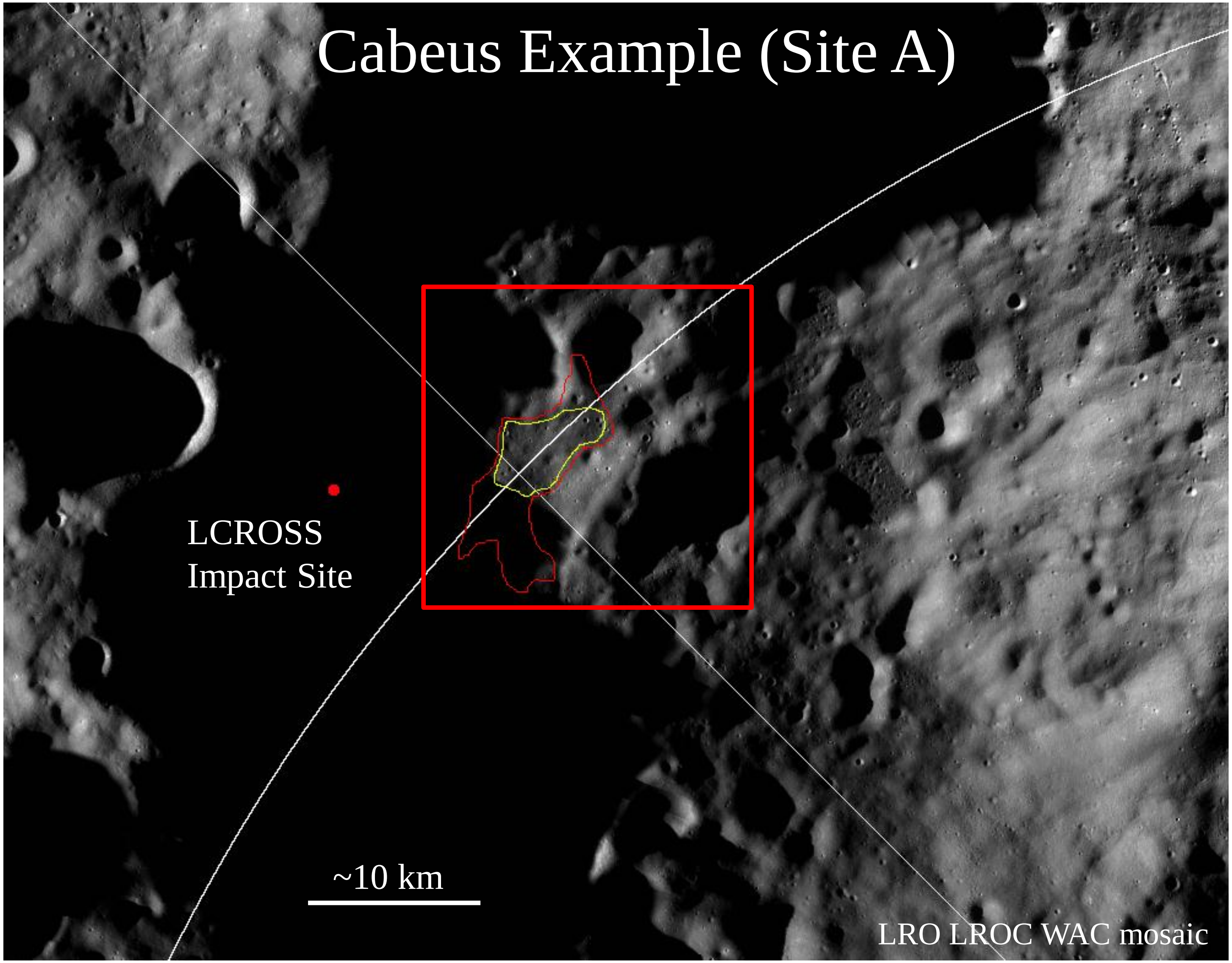


Sun and Shadow Ops

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

SUN (2.5 days)

- **Checkout**
  - *6.17 hrs*

- **1st Navigation 0.6 km**
  - *3.88 hrs, 0.6 km total*
- **Drill 1st Hole 4.33 hrs**
  - *Two 0.5m Augers (1-2)*
  - *One 1.0m Core (1)*
- **Process Segments (1-8)**
  - *8 segments, 26.84 hrs*

- **2nd Navigation 0.6 km**
  - *3.88 hrs, 1.2 km total*
- **Drill 2nd Hole 4.33 hours**
  - *Two 0.5m Augers (3-4)*
  - *One 1.0m Core (2)*
- **Process Segments (9-10)**
  - *2 segments, 9.59 hrs*

SHADOW (2 days)

- **Hibernate**
  - *48 hrs*
- *Consider using this "down time" to downlink detailed RESOLVE data (pics, detailed plant data, etc.)*

SUN (5 days)

- **Battery Recharge**
  - *6.8 hrs*

- **3rd Navigate 0.6 km**
  - *3.88 hrs, 1.8 km total*
- **Drill 3rd Hole 4.33 hrs**
  - *Two 0.5m Augers (5-6)*
  - *One 1.0m Core (3)*
- **Process Segments (11-15)**
  - *5 segments, 19.85 hrs*
  - *1st H2 Reduction*

- **4th Navigate 0.2 km**
  - *2.29 hrs, 2.0 km total*
- **Drill 4th Hole 4.33 hrs**
  - *Two 0.5 m Augers (7-8)*
  - *One 1.0m Core (4)*
- **Process Segments (16-20)**
  - *5 segments, 19.85 hrs*
  - *2nd H2 Reduction*

- **5th Navigate 1.0 km**
  - *5.47 hrs, 3.0 km total*
- **Drill 5th Hole 4.33 hrs**
  - *Two 0.5m Augers (9-10)*
  - *One 1.0m Core (5)*
- **Process Segments (21-25)**
  - *5 segments, 18.41 hrs*
  - *3rd H2 Reduction*

MISSION SUMMARY

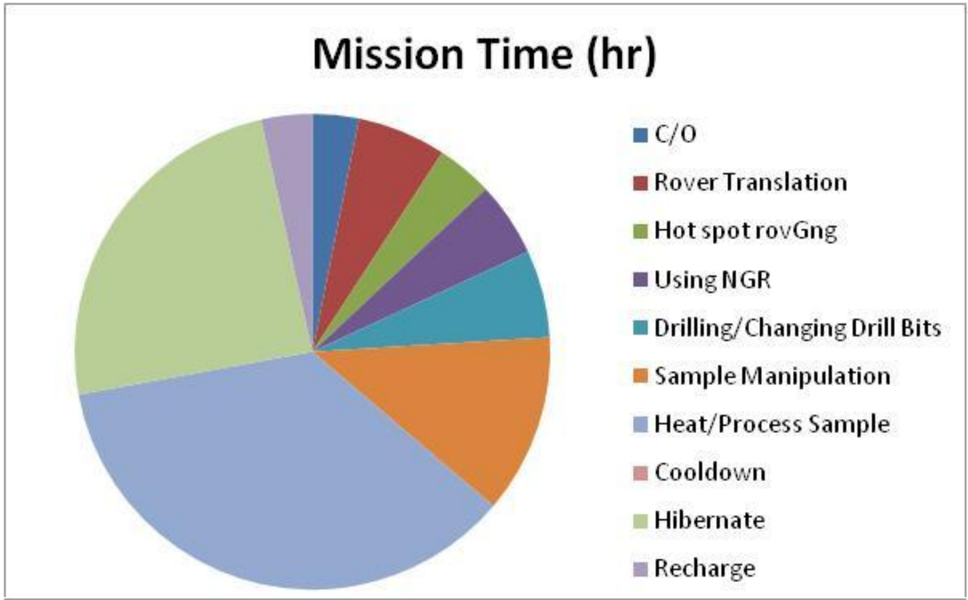
- Mission Length 9.5 days
  - 2.5 days Sun
  - 2.0 days Shadow
  - 5.0 days Sun
  - 8.2 days of Scheduled Activities
  - 1.3 days of Reserve Time
- Samples Processed
  - 25 processed at 150 deg C
  - 3 processed at 900 deg C
- Navigation
  - 5 navigation periods
  - Distance traveled is 3.0 km
- Drilling
  - Ten 0.5 m Augers
  - Five 1.0 m Cores

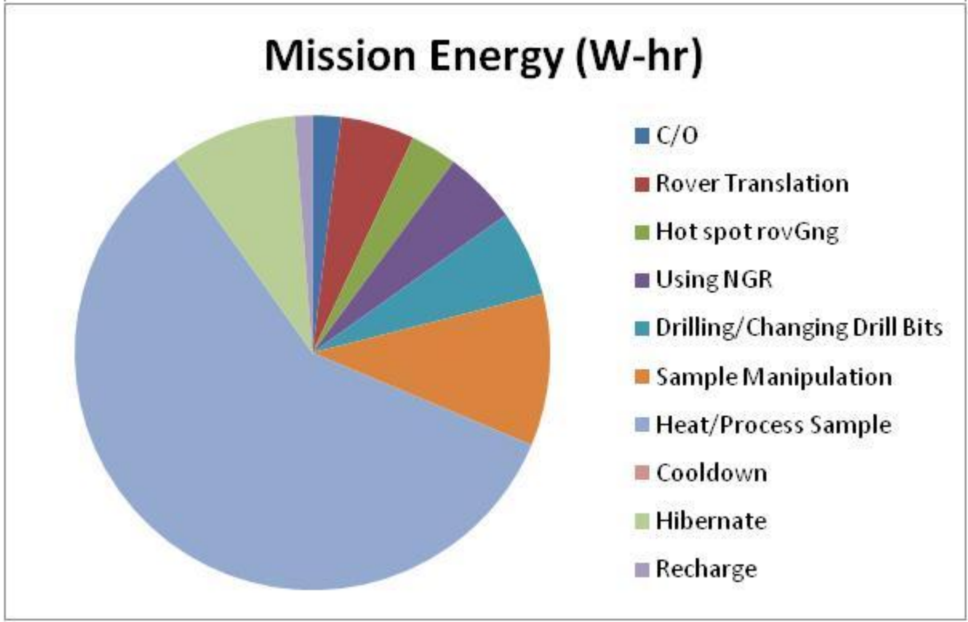
Time & Energy by Mission Function

(2.5 days Sun, 2 days Shadow, 5 days Sun)

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

	time (hr)	energy (W-hr)
C/O	6.17	684.77
Rover Translation	11.90	1754.76
Hot spot rovGng	7.50	1105.50
Using NGR	10.00	1765.00
Drilling/Changing Drill Bits	11.65	2056.23
Sample Manipulation	24.01	3620.82
Heat/Process Sample	70.53	20603.69
Cooldown	0.00	0.00
Hibernate	48.00	3024.00
Recharge	6.81	429.21
sum (hrs)	196.57	35043.97
sum (days)	8.190567	

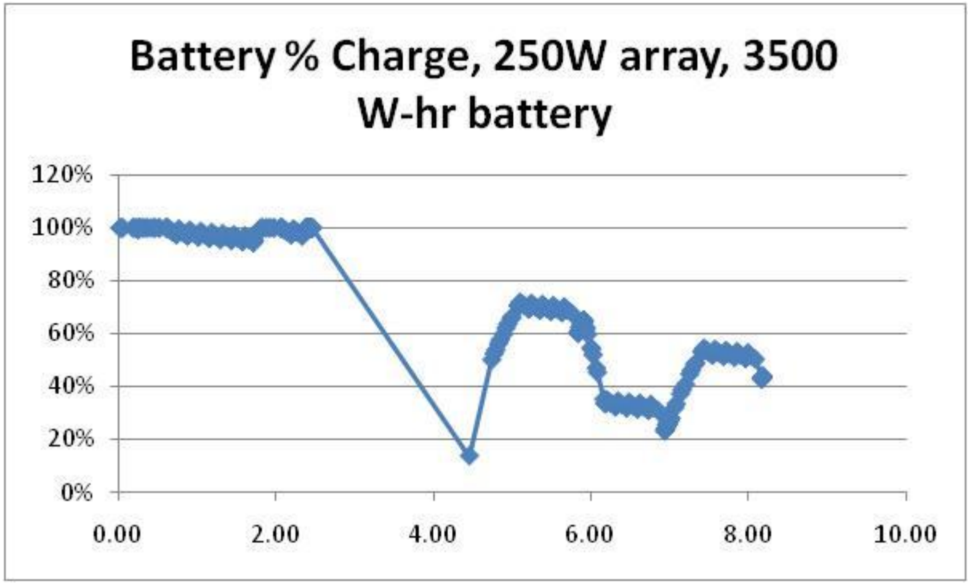




Time, Energy & Battery State of Charge by Segment
(2.5 days Sun, 2 days Shadow, 5 days Sun)

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

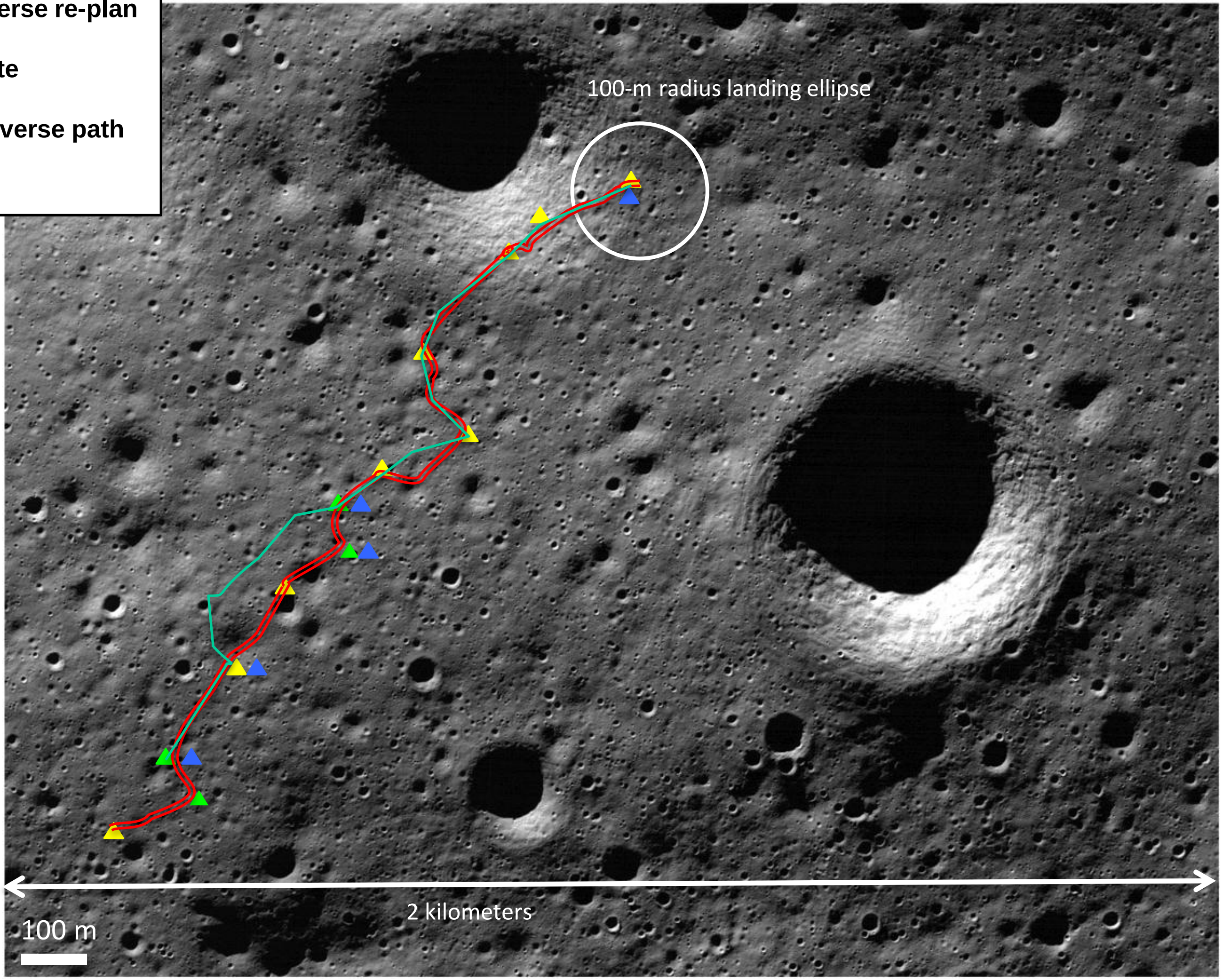
	time (hr)	energy (W-hr)
C/O	6.17	684.77
Nav 1	3.88	572.05
Drill 1	4.33	764.25
Process 1	26.84	6831.09
Nav 2	3.88	572.05
Drill 2	4.33	764.25
Process 2	9.59	2142.65
Hibernate + Recharge	54.81	3453.21
Nav 3	3.88	572.05
Drill 3	4.33	764.25
Process 3	19.85	5156.07
Nav 4	2.29	338.08
Drill 4	4.33	764.25
Process 4	19.85	5156.07
Nav 5	5.47	806.02
Drill 5	4.33	764.25
Process 5	18.41	4938.63
sum (hr)	196.57	35043.97
sum (days)	8.190567	



Notional Traverse Plan On Cabeus Floor

RESOLVE: Regolith & Environment Science and Oxygen & Lunar Volatile Extraction

- Major waypoint
- Discovery: traverse re-plan
- Core Sample site
- Pre-planned traverse path
- Executed path



The Path Foward

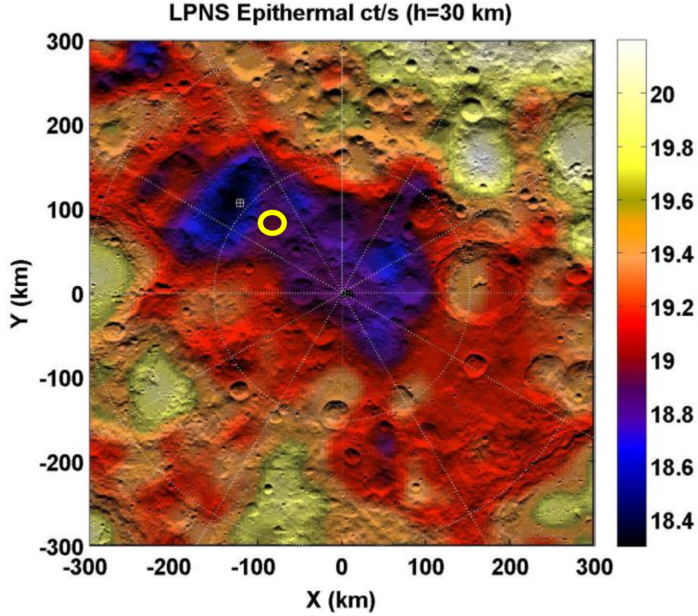
- RESOLVE and Rover Ground Demonstration Units (GDU)have completed their 90% design reviews and fabrication has begun
- Flight software development is underway
- Ground Development Units will used to conduct a mission simulation at a Lunar Analog Site (Mauna Kea, Hawaii) in the Summer of 2012.
- Flight Test Unit design begins this spring after initial integrated tests of RESOLVE GDU
- Goal is to have Flight Test Unit ready to go into thermal, vacuum and vibration testing by the fall of 2013.
- Hopefully, Commercial Lander capabilities will be coming on line in the 2014-15 timeframe due to the Google Lunar X-Prize.

"Sun&Shadow" Solar/Battery Rover Architecture

(Version 2.1, 2011-6-23)

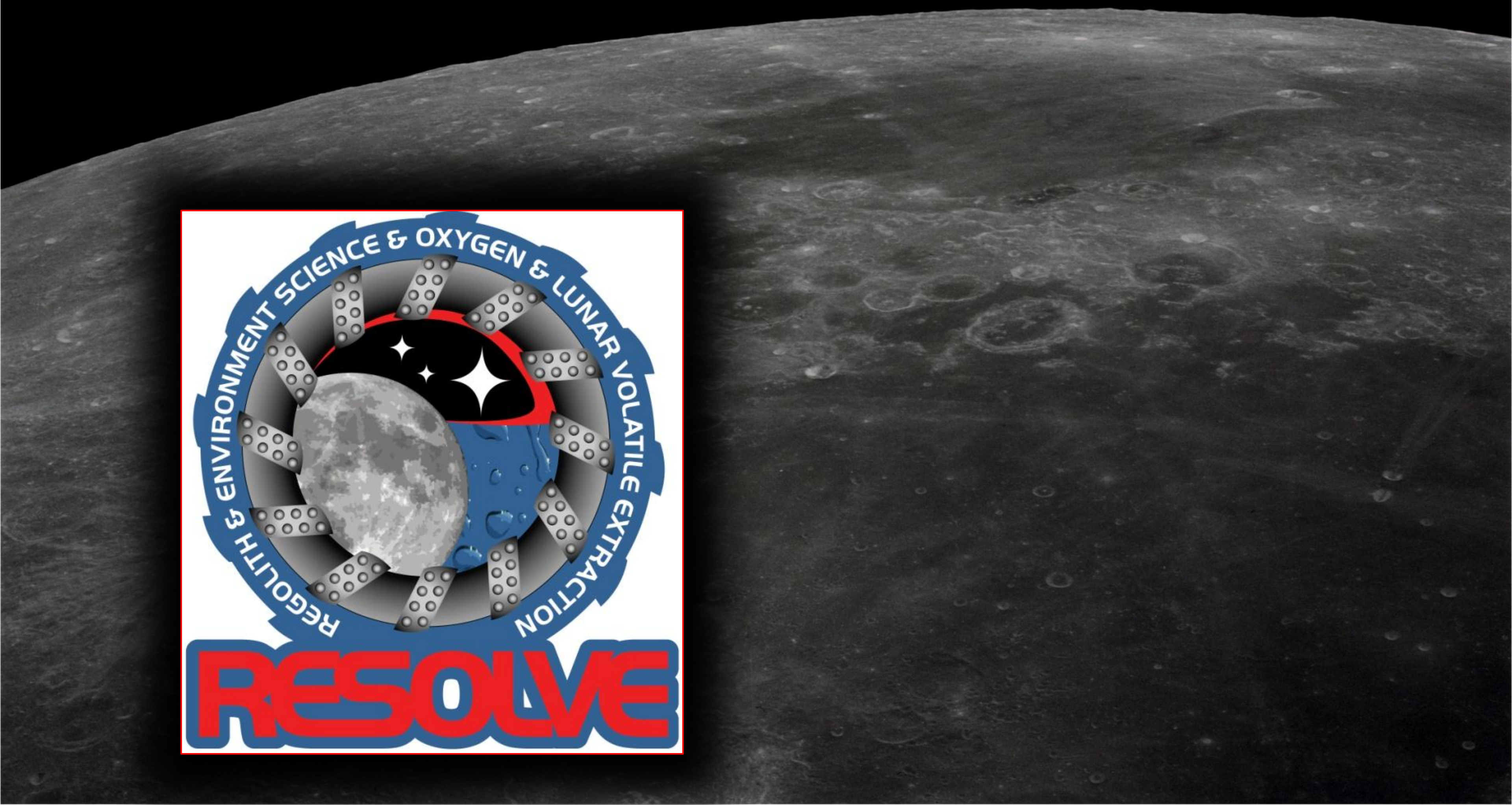
- **Destination:** Moon South Pole
- **Site:** Cabeus A1
  - Latitude: -85.75 deg
  - Longitude: -45 deg
- **Surface Mission Duration:** 9.5 days (7.5 w/ sun)
- **Primary Spacecraft:** Rover
- **Power Strategy:** Solar PV + Battery
  - Solar Array: 250 We
  - Secondary Battery: 3500 W-hr
- **Comm. Strategy:** Direct via McMurdo/Troll
- **Survey Track:** 3,000 m
- **Payload:**
  - Drill: 5x1m core, 10x0.5m auger
  - ISRU Reactor: 25@150C, 3@900C ISRU
  - Gas Chrom. / Mass Spec.: 25 samples
  - Neutron Spectrometer 3000m
  - Near-IR Spectrometer 3000m, 10 auger cuttings
- **Mission Energy:** 48,500 W-hr available
- **Mission Ave. Power:** 178 W predicted
- **Payload Mass:** 72 kg
- **Rover+P/L Mass:** 243 kg
- **Landed Mass:** 1285 kg
- **Wet Mass @ TLI:** 3,476 kg
- **Launch Vehicle Class:** Atlas V 411

Field Testing Rover Prototype



Cabeus South Pole Landing Site

QUESTIONS?


REGOLITH & ENVIRONMENT SCIENCE & OXYGEN & LUNAR VOLATILE EXTRACTION
RESOLVE

IAC-11-A5.1.4

RESOLVE: Ground Truth for Polar Lunar Volatiles as a Resource

William E Larson
NASA-Kennedy Space Center, USA, william.e.larson@nasa.gov
Martin Picard
Canadian Space Agency, Canada, martin.picard@asc-csa.gc.ca
Gerald B. Sanders
NASA-Johnson Space Center, USA, gerald.b.sanders@nasa.gov
Anthony Colaprete
NASA-Ames Research Center, USA, anthony.colaprete-1@nasa.gov
Richard C. Elphic
NASA-Ames Research Center, USA, richard.c.elphic@nasa.gov

Our understanding of the Moon has been evolving rapidly over the last few years. What the scientific community thought was a dry and barren wasteland from the samples brought home from the Apollo missions, has surprised the vast majority of lunar scientists by being a “wet” and dynamic body as you approach the poles. In the 1990’s Clementine and Lunar Prospector gave us hints that there might be water ice at the poles. This evidence was heatedly debated by the scientific community until the debate was ended dramatically by the impact of the Lunar Crater Observation and Sensing Satellite (LCROSS) in October of 2009. LCROSS indisputably showed that the Cabeus crater contained water ice. Additionally, instruments aboard the Lunar Reconnaissance Orbiter show evidence that the water ice may not be limited solely to the permanently shadowed regions. The only question that remains now is the distribution and quantity of water at the poles and whether this ice is a resource that can be utilized to enable the exploration of Space.
NASA’s In-Situ Resource Utilization project, in partnership with the Canadian Space Agency, is developing a payload that will enable us to provide ground truth answers to the question of water ice utilization on the Moon. The project is named RESOLVE, which is an acronym for Regolith & Environment Science, and Oxygen & Lunar Volatile Extraction. RESOLVE will land near the shadowed region of Cabeus at an area that receives sunlight for several days a month. Using a Neutron Spectrometer RESOLVE will map the distribution of hydrogen in both sunlit and shadowed regions near Cabeus. RESOLVE will also drill into the lunar surface up to a meter in depth using a augering/coring drill subsystem supplied by the Canadian Space Agency. A NIR spectrometer will be used to map bound surface water and hydroxyl (Pieters et al, 2009) and identify water and other volatiles in drill auger cuttings. After the core is acquired it will be heated in an oven to evolve the volatile gases that are frozen in the regolith. As the temperature increases, a Gas Chromatograph and a Mass Spectrometer will analyze the evolved gases. The Gas Chromatograph & Mass Spectrometer will allow us to identify and quantify the compounds of all of the volatiles species seen by LCROSS. The data obtained by RESOLVE will allow us to ascertain if the water ice and other volatile resources at the poles of the Moon could be effectively harvested and utilized in human exploration systems.

I. OUR EVOLVING UNDERSTANDING OF THE MOON

Apollo

In the 1960’s much of the world was caught up in the “Space Race” between the Soviet Union and the United States. The National Aeronautics and Space Administration (NASA) was mainly focused on the primary objective which had been laid out by President John F. Kennedy. That objective, as stated by President Kennedy, was “that [the] nation should commit itself to achieving the goal, before [the] decade is out, of landing a man on the Moon and returning him safely to the Earth.” There was no mention of what we would do on the Moon once we got there and in truth, science on Moon was somewhat of an afterthought.

In spite of this limited focus on science, each Apollo mission that landed on the Moon, carried a suite of experiments designed to help us learn about the Moon and Space environment. The Astronauts were also trained in field geology so that they could acquire samples of interest for the scientists to study upon their return. The Astronauts brought back a total of 382kg of lunar regolith and rocks. Most of these samples we collected from the surface but there were also 32 core tube samples collected during the program providing us with data at over 1.6m in depth. Scientists have studied these samples for years and the general conclusion was that the Moon was dryer than the driest desert on the earth.

That does not mean however, that it is devoid of resources. Oxygen makes up a significant percentage of the lunar regolith, roughly 42%.. This oxygen can be extracted from the regolith via thermo-chemical processes for utilization on human exploration missions. The regolith was also found to contain very small quantities of volatile gases which were implanted by the constant bombardment of the solar wind. Hydrogen, helium, carbon and nitrogen were found in the samples from every mission, but in quantities so low (< 150ppm at most) that vast quantities of regolith would have to be processed to make even the smallest amount of rocket fuel or water to drink.

A New View of the Moon

The view of a very dry Moon persisted into the mid 1990's, but in 1996 our view of the Moon was shaken up by the Bistatic Radar experiment on the Clementine mission. This experiment, which was conducted while Clementine was in orbit around the Moon, seemed to indicate that deposits of ice existed in permanently shadowed regions near the south pole of the Moon.[1] This interpretation was hotly debated in the lunar community and many felt this was a misinterpretation of the data. However, in 1998, the Lunar Prospector mission added more support to the belief that there was water in the permanent shadows near the poles. Lunar Prospector carried a Neutron Spectrometer into a polar orbit around the Moon. This spectrometer senses the presence of hydrogen in the regolith through the depletion of epithermal neutrons created by the collision of galactic cosmic radiation with atoms in the regolith. The instrument was designed to be able to detect hydrogen even if it was only at a concentration of 0.5% in the lunar soil. In late 1998, data was released that included an estimate that there was at least $3x10^9$ metric tons of water ice in the polar regions of the Moon.[2] Even with data from two different instruments, the conclusions were still widely debated, with one lunar scientist allegedly stating that he would eat his shorts if there was water on the Moon.

LCROSS Makes a Splash

The debate continued for another 10 years with one camp or another revealing a new analysis that either supported or disputed the presence of water ice on the Moon. In 2009, the debate was brought to an abrupt conclusion with the impact of the Lunar Crater Observation and Sensing Satellite (LCROSS). LCROSS was a secondary payload carried into space with the launch of the Lunar Reconnaissance Orbiter (LRO). LCROSS was designed to crash the Centaur upper stage of the launch vehicle into a permanently shadowed crater to eject material up above the lunar surface and into the sunlight. Then the LCROSS shepherding spacecraft, traveling just a few minutes behind would image the sunlit plume to identify the compounds and elements present at the impact site. The LCROSS instrument suite included ultraviolet, visible and near infrared spectrometers to provide compositional data, and a variety of visible, NIR and thermal cameras to help constrain impact dynamics and total ejecta mass. With respect to water identification, two lines of evidence came from the UV/Visible spectrometer and NIR spectrometer. In the ultraviolet hydroxyl (OH) was identified. The emission structure measured was consistent with the photolysis of water vapor. In the NIR spectrometer even more direct identification of water was made via the observation of water vapor and ice bands.[3] In addition to water, both the UV/Visible and NIR spectra revealed a number of other volatile compounds, including carbon dioxide, formaldehyde, and hydrogen sulphide.

LRO also observed the ejecta plume from the impact with its Lyman Alpha Mapping Project (LAMP) which observes in the far-ultraviolet. LAMP observed a gas plume high over the impact site that contained molecular hydrogen (H_2), mercury, and carbon monoxide as well as water. [4]

Questions Remain

While LCROSS and LRO have now proven the existence of water and other valuable resources at the poles of the Moon, there are still questions with regard to their viability as a resource for human exploration. While MiniSAR on-board LRO detects evidence of ice in the permanent shadows, the data from the Lunar Exploration Neutron Detector (LEND) does not always see elevated hydrogen in these same craters. Perhaps that can be explained by the fact that LEND can only "see" about half as far beneath the surface as the MiniSAR. But that's only one of the paradoxes seen in the data. LEND "sees" elevated areas of hydrogen that are outside of permanent shadow in areas yet MiniSAR doesn't "see" ice in these areas. There can be a variety of explanations for these apparently conflicting data sets, but the only sure way to answer the questions is to seen a mission to the surface of the Moon to provide direct measurements that will unequivocally answer the questions. . Furthermore, while the LCROSS impact did reveal water ice, it did so in only one spot. If the concentration of water derived from the LCROSS observations are correct, it suggests that the distribution of water within a PSR is non-uniform, with patches of higher ice concentrations separated by some distance of drier regolith. Also, the LCROSS impact sampled in depth rather coarsely. The majority of ejecta which reached sunlight originated between the surface and 1meter. There is very little information from the LCROSS impact with regards to how the observed water ice is distributed in the topmost meter (an important spatial extant as it is across this depth that neutron measurements are sensitive). A critical piece of information needed is the distribution of water at scales less than and across one kilometer. Thus, multiple measurements must be made; a survey of the distribution of water and other volatiles is needed.

II. IMPORTANCE OF LUNAR RESOURCES

The confirmation of volatile resource on the poles of the Moon has significant implications for human exploration. Harvesting these resources changes the human exploration architecture. Harvesting water ice eliminates the need to bring water from the earth for human consumption and hygiene needs. If we electrolyze the water, we can provide the oxygen needed for life support. The hydrogen and oxygen can be used to power mobility systems via a fuel cell. However, the most important use for in-situ resources is in the production of propellant.

Propellant makes up over 75% of every launch vehicle's mass. Each Stage of the launch vehicle has to be able to lift the combined masses of the elements above it. But a significant portion of the total propellant load as the rocket sits on the launch pad, isn't required for the first state of the mission, getting to earth orbit. If we didn't have to fuel these elements of the launch vehicle, the initial launch mass could be considerably less, and hence cheaper. When fuel is available in space, it opens up completely different mission architectures. The ability to refuel on the lunar surface allows the concept of a reusable Lander to be introduced. Now each mission to the Moon doesn't have to carry the mass of the lunar lander. If we carry the concept further and establish propellant depots in lunar or earth orbit, supplied by lunar resources, we can refuel the transfer stages that take us from earth orbit to lunar orbit and return. Reducing the size and number of launches required, drops the cost of human exploration and opens up destinations in deep space that would be virtually impossible to conduct using an Apollo style mission architecture.

Before we can introduce these revolutionary architectures to human (or robotic) exploration, NASA must go beyond the theoretical and determine if utilizing water ice on the Moon is possible. To do that, we must solve the riddles remaining in our lunar data sets. We also need to know many of the same things that mining companies need to know before investing in a new mine. We must have answers to questions like: What is the concentration and distribution of the resource of interest? What form will the resource be found in? What is the overburden and how much of it must be removed before we can access the resource? All of these questions need to be answered before we can establish our "mine" on the Moon.

NASA's In-Situ Resource Utilization project has been investing in the development of a payload that can ground truth lunar water ice and other valuable resources that LRO and LCROSS have identified. It is being designed to answer the resource prospecting questions that will enable us to consider the practicality of setting up our mining operation on the Moon. Now that the payload instruments are maturing, we are also beginning to develop the mission operations scenarios needed to deliver answers to our questions and hopefully take the first step towards changing the way we explore Space forever.

III. OBTAINING GROUND TRUTH

Shadowed Crater or Partial Sunlight?

In order to design a payload to meet the objective of demonstrating that water ice is a practical resource on the Moon, it is necessary to step back and analyze where we would go and what we need to do when we get there. Ultimately, the mission needs to prove not only the availability of water ice (and other volatiles) as well as their viability for utilization in human exploration mission architectures. So it is important to examine the LRO and LCROSS data as the initial step of selecting needed payload capabilities and a robotic mission architecture.

As discussed above, LRO and LCROSS data provides us with several target areas where we could send our ground truth mission. We could go to the permanent shadowed craters. This appears to be the place where we are likely to locate the most water ice and other resources. But the permanent shadows present many challenges to mission success. Just as their name indicates, the mission would have to operate in total darkness. Not only will it be dark, but it will be extraordinarily cold. Some of the measurements made by Diviner of permanently shadowed craters indicate that the temperature at the bottom of some of the craters is 25° K. That's almost cold enough to liquefy hydrogen! Designing a payload to operate in this environment for extended periods would require a nuclear energy source, driving up the mission cost exponentially. This begins to raise the question of practicality for our lunar water ice mine. Could we really set up a mining operation in such a harsh environment? It may be possible, but it would certainly require leaps in material, power and lubricant technologies. Alternatively, we could look for water ice in some of the areas that the LEND sees elevated hydrogen outside of the permanently shadowed craters. In these locations the sun is available to us as an energy source. The operating temperature is a much more manageable 175-225°K where we have the technology and experience to design spaceflight hardware. This combination of factors makes the mission much more affordable and it becomes easier to envision the establishment of a mining operation should we discover recoverable resources during our surface mission.

An examination of several of the LRO datasets reveals we can find a number of places on the Moon where we could conduct our mission. Most of the analysis has been in the South Polar Region, but it is likely that analysis of the North Polar Region would yield similar results. The landing site that we will target for this mission would land above 80° latitude in an area that receives several days of sunlight each month. The mission would be timed to land at the selected pole's summer for maximum earth visibility for communications and maximum sunlight duration for power. Having the mission powered by the sun is critical to keep the mission costs low. Missions requiring nuclear-based power sources are likely too expensive and also impractical at this time for a commercially-provided delivery system. We also want the mission to land at a location where orbital data indicates we are likely to find the volatile resources not available in quantity elsewhere on the Moon. Finally, we need to land on terrain that is reasonably navigable by mobility platforms currently available. This seems like a difficult set of constraints to meet, however the ISRU science team has found several locations, marked with circles A, B & C in the following figures, that meet the requirements to demonstrate the production of oxygen and volatile gases. For orientation purposes, the South Pole is located at the vertices just below the letter "C". The locations shown are for illustrative purposes only. They serve only to demonstrate that the mission architecture proposed is possible. The ultimate landing location will be chosen based on a more detailed analysis of the LRO datasets.

Landing Site Selection

The set of figures below represents several data sets from either the Lunar Reconnaissance Orbiter or ground-based observations. Each has been reviewed for applicability to a Lunar Volatiles/Oxygen mission. As stated previously, oxygen can be produced from the regolith's minerals anywhere on the Moon. So the analysis focuses on the evidence of water ice, sunlight availability, earth communications availability and slopes that are reasonably drivable by a rover.

The first data set we need to look at is where we might find water ice in the regolith. To do that, we need to find places that are cold enough to support the existence of water ice in a vacuum for eons of time. For that to happen, the temperature needs to be at or below 100° Kelvin.

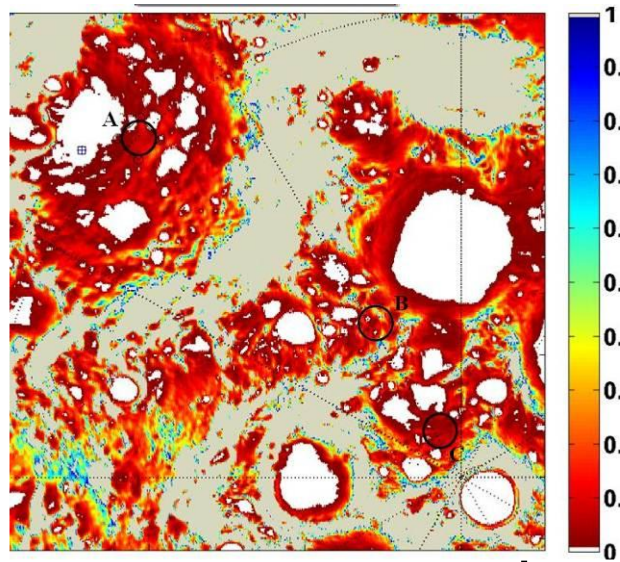


Figure 1: Depth to "Stable" Water Ice[5]

Figure 1 above is based on data from the Diviner imaging thermal radiometer instrument on LRO. Diviner measures the infrared emissions from the Moon and from this data the temperature of the surface of the Moon can be inferred. Since we know the thermal conductivity of the lunar soil and have subsurface temperature measurement from the Apollo program, the temperature beneath the surface can be reasonably calculated. Water ice is very stable in a vacuum at temperatures below 100°K. At that temperature, water ice can last over a billion years without significant sublimation. Figure 1 is color coded to show the depth at which the subsurface temperature could reasonably be expected to be 100°K or below. The white areas are the permanently shadowed features at the poles. It's very clear from the many dark red areas in this figure that there are many places at the poles that have temperatures just 0.1m below the surface that could support the existence of water ice. Areas A, B and C are marked again in this figure and show that our magic number of 100°K is just 0.1m below the surface. The next step in the analysis is determining if there is any indication of water ice in these areas.

Figure 2 represents the data returned by the Lunar Exploration Neutron Detection, or LEND. The chart is overlaid on the previous temperature data chart. LEND senses hydrogen due to the depletion of epithermal neutrons caused by the presence of hydrogen or hydrogen bearing compounds. It can "see" about a meter beneath the surface. The dark blue areas of the figure represent the highest areas of hydrogen concentrations. Note that circle A in the figure has a high degree of neutron depletion (high hydrogen). This is very near the impact site of the LCROSS mission and is located in a partially sunlit section of the Cabeus crater floor. Circles B & C also represent areas of higher than average hydrogen concentrations in the upper meter of lunar soil. So now we have located a region that is cold enough for water ice and shows evidence from orbit of the presence of water ice.

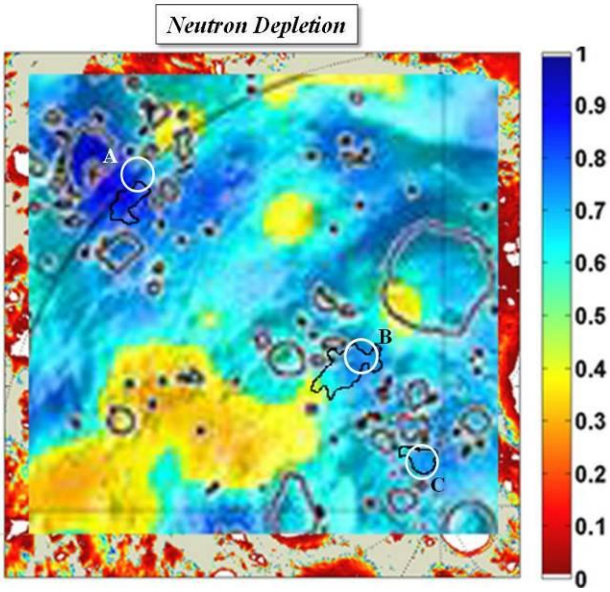


Figure 2: Credit: I. Mitrofanov & Team, 2010

Now that we've found a few places where we can reasonably expect to find water ice and/or volatile resources, the team analyzed other elements that would impact the mission design. Figure 3 shows the number of days of sunlight a South Pole Region of the Moon will see during the polar summer.

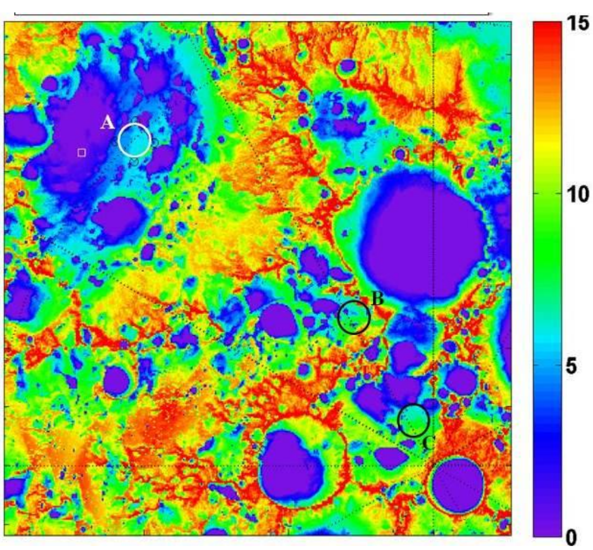


Figure 3: Days of Sunlight South Pole Summer

This data is based on the topographic data returned by the Lunar Orbiter Laser Altimeter, or LOLA. LOLA is generating the most accurate topography maps, with up to a meter accuracy of the poles we've ever had, which allows for very accurate sun/shade maps to be generated. The red areas of the map below receive the greatest number of days of sunlight a month and the purple areas receive no sunlight at all. While it would be ideal if our mission could go to an area that receives a full 15 days of sunlight a month, unfortunately, those areas do not have cold enough temperatures to support the existence of water ice and volatiles. However, as can be seen in the figure the areas we identified before, A, B and C, receive at least 5 days of sunlight in the summer. This should be enough time to demonstrate the production of oxygen and survey the area for volatile resources.

The next step in the analysis is to insure that we have a direct to earth communications link. Figure 4 above shows that areas A, B and C have direct to earth communications windows during the polar summer. This eliminates the need for a communications relay satellite, keeping the mission in the range of affordability.

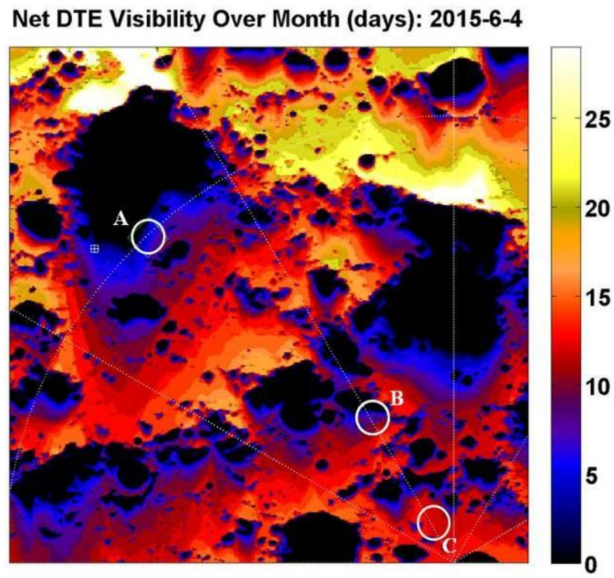


Figure 4: Direct to Earth Communication Days

Even though we have strong evidence that there is hydrogen or hydrogen-bearing compounds in the near subsurface in these areas we've analyzed, it is important to remember that orbital data has pixel sizes that can be rather large (>10km). So while the orbital data gives us a good idea of the general location to look for resources, the mission needs to include mobility to insure mission success and ground truth the distribution of the resources seen by orbiting instruments. In order to minimize the challenges the mobility platform would face, the team wanted to select a landing site that had gentle slopes. Figure 5 uses topography data derived from LOLA to estimate the slope of the terrain. Each of the selected areas has average slopes of about 5 to 10 degrees. These types of slopes can easily be navigated by mobility platforms currently available from the both private and governmental sources.

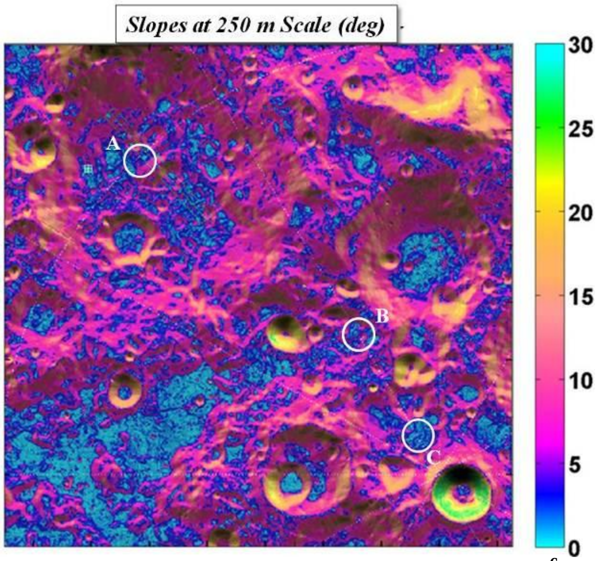


Figure 5: Slope of Terrain Based LOLA Data[6]

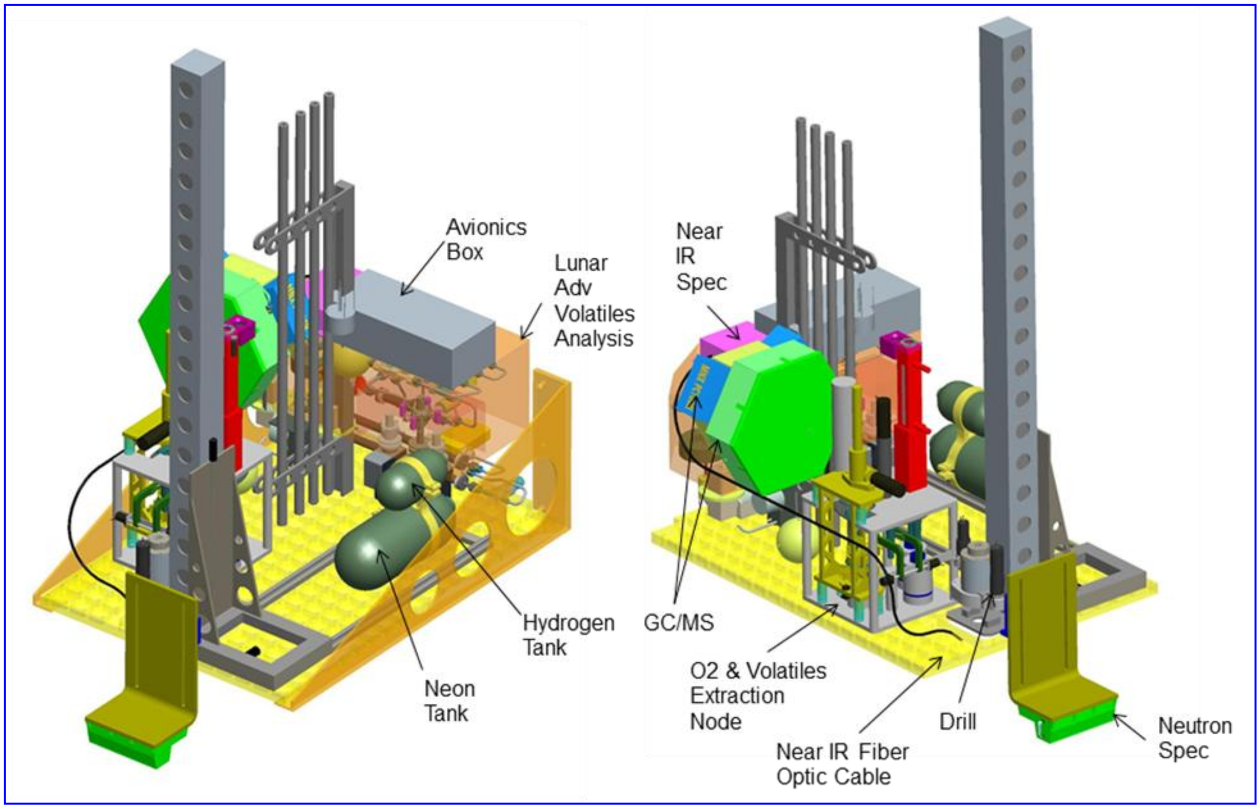
IV. THE RESOLVE PAYLOAD

Based on the data review presented above the project team was able to select a mission architecture to bound the technology needs to meet the project's objectives. The current mission concept requires a rover mounted payload. The payload consists of a prospecting instrument, Neutron Spectrometer (NS) to locate areas of high hydrogen concentration to insure that we get an appropriate sample of the regolith. A Near Infrared (NIR) spectrometer assists in prospecting by identifying any surface volatiles and providing mineralogical context. A Sample Acquisition Subsystem (SAS) provided by the Canadian Space Agency will acquire a one meter deep sample of regolith. The sample will be incrementally introduced into a reactor subsystem, Oxygen & Volatiles Extraction Node (OVEN), where it will be heated step by step to 150°C. As the sample is heated, the gases evolved from the sample will be identified and quantified by a gas analysis subsystem, named Lunar Advanced Volatiles Analysis, or LAVA. Any water that is evolved will be condensed and photographed. The sample will then be heated to 900°C. At that point, hydrogen gas will be introduced into the reactor. This will result in a reaction with the iron oxides contained in the regolith that produces water. The water will again be quantified by the gas analysis subsystem. This process will be repeated several times at different locations within a kilometer of the landing site to allow a resource distribution map to be generated.

The core drill coupled with OVEN and LAVA provides quantitative data on the concentration of volatiles in the lunar regolith, however the process is very time consuming. Since we have a limited time with available sunlight to conduct the mission the RESOLVE payload design also offers a subsurface "quick look" capability. For a quick look at the subsurface, the CSA provided SAS swaps out the coring drill for an auger tool. The auger is used to bring subsurface material to the surface where it can be examined by the NIR spectrometer. These quick-looks, combined with the NS data set, will help to constrain the depth of the hydrogen source observed by the NS. The physical layout of the RESOLVE subsystems is shown in the figure on the following page. Additional detail on each of these major subsystems is described in the following paragraphs.

The Neutron Spectrometer Subsystem

The Neutron Spectrometer Subsystem (NSS) is our mission "bloodhound" and it is an essential element of the RESOLVE instrument suite. While we see elevated levels of hydrogen from orbit, the pixel size from orbit is several 10's of square kilometres. So it's impossible to know whether the elevated hydrogen signal comes from a broad area of evenly dispersed hydrogen or a large concentration of hydrogen, presumably water ice, within the field of view of the orbital LEND instrument. Having the neutron spectrometer on board RESOLVE allows us to localize the elevated hydrogen concentrations so we know where it would be best to collect a subsurface sample.



The NSS instrument that will be developed for RESOLVE has flight heritage having flown on orbiting missions such as Lunar Prospector, Mars Odyssey, Mercury MESSENGER, and Lunar Reconnaissance Orbiter. However, the instrument must be modified to operate as a surface-based instrument which will require hardware modifications and improvements. The NSS instrument development will demonstrate the unique capability of the technique to measure water (in the form of hydrogen) at a concentration of approximately 1 weight percent at a depth of 1 meter. The NSS instrument detects the equilibrium neutron flux emitted from the surface of the planetary body. On the surface of the Moon, galactic cosmic rays (GCRs) impinge on the surface producing high energy neutrons (>10 MeV), which are then slowed by collisions in the surface materials. These collisions result in a moderated neutron flux composed of thermal (0.01– 0.4 eV) and epithermal (0.4 eV – 500 keV) neutrons indicative of the composition of the material. Hydrogen is a good neutron moderator resulting in an increase of thermal neutron flux and a decrease of epithermal neutron flux.

Sample Acquisition Subsystem (SAS)

Once the NSS has located an interesting location to be sampled, the Sample Acquisition Subsystem (SAS) is activated to acquire a subsurface sample. The SAS is being developed for RESOLVE by the Canadian Space Agency through a contract with the Northern Centre for Advanced Technologies, Inc. The SAS's primary job is to provide a one meter subsurface sample of the lunar regolith. The SAS actually has three tools available to provide a sample. The first is basically an Auger tool whose flutes bring the regolith up to the surface where it can be observed by the Near Infrared Spectrometer. The second tool is actually a coring drill that will pull up an intact sample that can be segmented and passed along to the OVEN subsystem for heating and subsequent analysis by the LAVA subsystem. The third is a smooth push tube designed specifically for use in unconsolidated or loosely consolidated regolith. While this all sounds fairly straight forward on the surface, these drilling tools present significant technical challenges. It is important to keep in mind that we are trying to acquire a sample of water ice in a hard vacuum. If we heat the sample too much as it is drilled, the water ice will begin to quickly sublime. So the penetration rate, the drill speed and the drill/auger geometry all have to be carefully balanced in order to prevent loss of sample. The coring drill presents additional challenges because of the characteristics of lunar regolith. Its ultra-fine, angular nature, makes it very susceptible to forming material bridges which block the entry of regolith into the core tube. Thus the drill design has been through several iterations over the last few years to find a design that meets all design objectives.

Near Infrared (NIR) Spectrometer

This instrument will be used in conjunction with the NSS to help map surface material distributions and in conjunction with the Drill Subsystem to better understand the distribution of materials at various depths, provide additional characterization of higher mass compounds not measured with the gas analysis subsystem (e.g., hydrocarbons), mineralogical context for the sample sight, and the form of the water (e.g. ice vs. adsorbed). In addition, the NIR Spectrometer Subsystem will be capable of detecting volatile gases outgassing from the drill site. The existing NIR Spectrometer Subsystem consists of a flight spare from the Lunar CRater Observation and Sensing Satellite (LCROSS) mission. This LCROSS flight spare is capable of measuring in the range of 1.3-2.3 µm. While this range does include the first two water over tones, the water fundamental absorption band at 3.1 µm is approximately 50x stronger in terms of its absorption signature. For this mission, the NIR spectrometer wavelength coverage will be optimized for water detection in a relatively small field of view spot size (e.g. as observed from a surface asset). The NIR spectrometer hardware proposed will seek to have a spectral range from λ 1.8–3.2µm and spectral resolution of < 0.015 µm/resolution. This range requires a different detector than what was used on the LCROSS mission, and is being developed based upon the results acquired from this mission.

Oxygen and Volatile Extraction Node (OVEN) Subsystem

As stated earlier, neither the form of the hydrogen detected by the Lunar Prospector mission nor the exact point-to-point variation of the concentration was discernible from the data. Models predict the observed hydrogen enrichments as being a result of solar wind hydrogen, water ice formed after soil grains have been bombarded with solar wind hydrogen, and more complex ices released by impacting comets. These deposits could form thin films around regolith grains, partially to completely filling pore spaces, or form layers of ice (in the case of comet impacts). In the case of the latter, water would be the most abundant volatile (approximately 80%), but could be accompanied by other frozen compounds (carbon monoxide, carbon dioxide, methane, ammonia, etc.). The OVEN Subsystem will accept samples from the Drill Subsystem and will evolve the volatiles contained in the sample by heating the regolith in a sealed chamber. As a minimum, the temperature, pressure, and pressure rise rate of the vapors generated will be recorded as a function of heater power/temperature and time. The evolved gas/vapor will then be passed to the Lunar Advanced Volatile Analysis (LAVA) Subsystem.

If water is present in the permanently shadowed region of the lunar poles in usable and accessible concentrations, then large quantities of oxygen are easily available for future use at that site of exploration. However, at other locations on the Moon, or if water is not present, a different method for obtaining oxygen is required. The Moon is 42% oxygen (O_2) by mass, but it is in the form of metal and non-metal oxides and silicates. Numerous studies have been performed on lunar ISRU production process options for extracting the oxygen from lunar regolith. Most laboratory efforts have focused on three methods; H_2 reduction of ilmenite and pyroclastic glass, carbothermal reduction of lunar silicate, and molten silicate electrolysis. Extensive industry, academic, and NASA experience with developing similar ISRU hardware indicate that the H_2 reduction process best fits the demonstration scale mission.

Hydrogen reduction would nominally take place after the volatiles analysis of the sample was complete. The temperature in the OVEN after the last volatiles analysis would be raised to between 900° and 1000° C. At that point, hydrogen gas would be introduced into the OVEN. The hydrogen would react with the ilmenite and iron oxide bearing glasses to produce water. This water would be analyzed and quantified in the LAVA subsystem described below.

Lunar Advanced Volatiles Analysis (LAVA) Subsystem

This subsystem will accept the effluent gas/vapor from the OVEN Subsystem. The evolved gases from the OVEN Subsystem will be analyzed and quantified. The goal is to measure quantities and species of volatiles released below atomic number 70 (including H_2, He, CO, CO_2, CH_4, H_2O, N_2, NH_3, H_2S, SO_2) and survive limited exposure to HF, HCl, and Hg without interfering with continued operation of the instrument. We also need to be able to determine the isotopic ratio of the volatiles released from the regoltih. To achieve these measurement objectives a gas chromatograph and mass spectrometer combination will be used. Any water produced by the OVEN subsystem will be removed from the gas stream after quantification and transferred to LAVA where it will be condensed into a droplet so that it can be photographed for display to the public. LAVA will also provide the capability to process gas produced during the hydrogen reduction phase of OVEN operation. It will quantify the water produced by the hydrogen reduction process and perform analysis and quantification of the contaminant by-products that the hydrogen reduction process is expected to produce.

V. NOTIONAL MISSION TIMELINE

The hardware described in the previous section is well into its design phase. A ground test version of the hardware will come together for testing in the first half of 2011. What remained to be worked in detail was the mission plan. So recently a mission planning team was commissioned to do a detailed analysis of a mission to the Cabeus region of the South Pole (circle A on the preceding figures). The goal was to understand the true availability of power and communications. This is extremely important because although the target landing zone has 5 or more days of sunlight and communications, there are eclipse periods for both. Understanding the eclipse periods for sunlight helps the power system to be appropriately sized. Understanding the availability of communications will affect the degree of autonomy needed by the mobility system and the payload. The volume of work this team performed could be the subject of another paper, but will be summarized in the next few paragraphs.

Using topography maps generated using LRO's laser altimeter members of the team analysed areas in the Cabeus region that met our criteria for sun, communications, slopes, temperature and of course, hydrogen. The team targeted the May/June timeframe in 2015 and 2016 as the most likely mission execution dates. What they found upon detailed analysis was that there is no such thing as continuous sunlight or communications in this polar region. However, there are locations where the dropouts of sunlight or communications is tolerable. Tolerable in this case does not mean that there aren't considerable challenges in both sunlight for power and line of sight to earth for communications.

After looking at a number of potential landing sites to the south of Cabeus, a site at Latitude = -85.75 deg, Longitude = -45 deg was selected as RESOLVE's design reference mission. The availability of sunlight and communications is shown in Figures 7 and 8 for a mission conducted at the southern polar region in the lunar summer of 2016. In each figure a vertical line indicates the start and stop times for either Sun or Communications. A horizontal line is drawn between the two vertical lines when sun or communications is available. So it can be seen that during the first 2.5 earth days of the mission there is plenty of sunlight with only an occasional eclipse. However, after 2.5 days the sun is hidden from view for 2 full earth days. Therefore, the payload must have the battery capacity to survive the eclipse before resuming operations when the sun comes back into view. Similarly, the communications figure shows that we have reasonably good communications throughout the mission, but that the payload will need some degree of autonomy to avoid the loss of time when communications dropouts occur. But the communications dropouts shown on this figure are likely a worst case scenario. It is based on communications only through McMurdo Station in Antarctica. If the communications of Norway's Troll Research Station were upgraded (as expected) for S-Band communications, then virtually all of the communications dropouts could be eliminated. This works well into our desire to teleoperate the rover for most of its traverses.

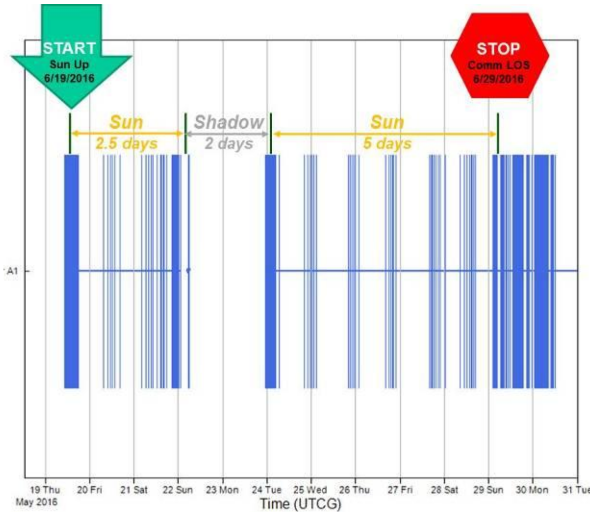


Figure 7: Sunlight at Landing Site May '16

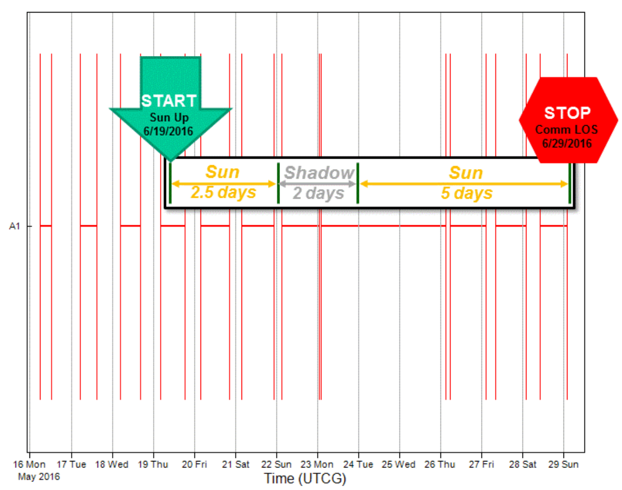


Figure 8: Communications at Landing Site May '16

In order to conduct the mission successfully, the mission operations team must be able to work within a very tight timeline to optimize the available sunlight. While the timeline is still in the early stages of development, the initial draft of the timeline for the Design Reference Mission indicates that even with the eclipses and communications dropouts, RESOLVE should be able to accomplish its primary objectives. Figure 9 shows the basic mission timeline and sequence of events.

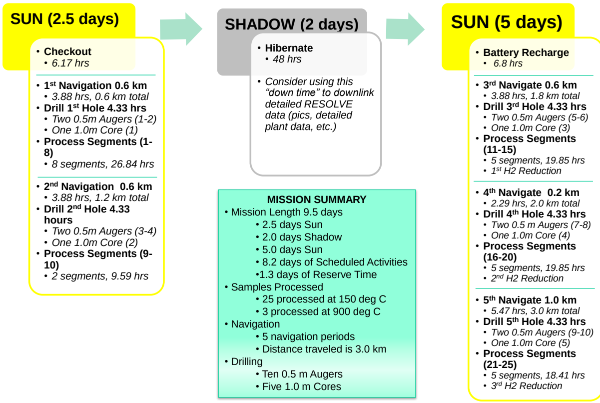


Figure 9: Baseline RESOLVE Mission Timeline

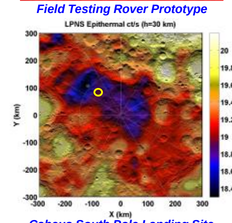
VI. THE PATH FORWARD

The mission analysis and the design activities of the RESOLVE team gives the authors a high degree of confidence that a mission to understand the quantity and distribution of water ice near the lunar poles can be accomplished. The RESOLVE design team has recently completed its 90% design review for the Ground Demonstration Unit. This unit will be assembled and integrated on a couple of different rover platforms (one NASA and the other CSA). Then a mission simulation will be conducted at a lunar analog site on the slope of the Hawaiian volcano, Mauna Kea. That test is currently schedule for the Summer of 2012. The field demonstration will be designed as a flight simulation, with command and control consoles and real time path planning set up as though we are executing the mission on the Moon. This will help train both the flight controllers and the mission planning teams with flight like challenges. It will also give hardware designers an opportunity to test their hardware outside of a laboratory environment, preparing them for the final flight development phase of the project.

As the field deployment of the Ground Demonstration Unit comes to a close the design team will initiate the Flight Development Unit design. Based on the design activities to date the design team has been able to develop a realistic estimate of the mass and power for the flight system. These targets along with an overall mission summary are shown in Figure10.

▪ **Destination:**	**Moon South Pole**
Site:	**Cabeus A1**
Latitude	-85.75 deg
Longitude	-45 deg
▪ **Surface Mission Duration:**	**9.5 days** (7.5 w/ sun)
▪ **Primary Spacecraft:**	**Rover**
▪ **Power Strategy:**	**Solar PV + Battery**
Solar Array	250 We
Secondary Battery	3500 W-hr
▪ **Comm. Strategy:**	**DTE McMurdo**
▪ **Survey Track:**	**3,000 m**
▪ **Payload:**	
Drill	5x1m core, 10x0.5m auger
ISRU Reactor	25@150C, 3@900C ISRU
Gas Chrom. / Mass Spec.	25 samples
Neutron Spectrometer	3000m
Near-IR Spectrometer	3000m, 10 auger cuttings
▪ **Mission Energy:**	**48,500 W-hr** available
▪ **Mission Ave. Power:**	**178 W** predicted
▪ **Payload Mass:**	**72 kg**
▪ **Rover+P/L Mass:**	**243 kg**
▪ **Landed Mass:**	**1285 kg**
▪ **Wet Mass @ TLI:**	**3,476 kg**
▪ **Launch Vehicle:**	**Atlas V 411**

Field Testing Rover Prototype



Cabeus South Pole Landing Site

Figure 10: RESOLVE Payload/Mission Summary

Our goal is to have hardware beginning flight certification tests by the fall of 2013. By then it is our expectation that commercial lunar delivery capabilities will become available and will have the capability to deliver our payload to the South Pole of the Moon opening the door to a new paradigm for the exploration of the solar system.

VII. ACKNOWLEDGEMENTS

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[1] Nozette, S., Lichtenberg, C.L. Spudis, P.D., Bonner, R., Ort, W., Malaret, E., Robinson, M., and Shoemaker, E.M., 1996, The Clementine Bistatic Radar Experiment, *Science*, vol. 274, p. 1495-1498

[2] Feldman, W.C., Maurice, S., Binder. A.B., Barraclough, B.L., Elphic, R.C., and Lawrence, D.J., 1998, Fluxes of Fast and Epithermal Neutrons from Lunar Prospector: Evidence for Water Ice at the Lunar Poles, *Science*, vol 281 p.1496-1500

[3] Colaprete A., Schultz, P., Heldman, J., Wooden, D., Shirley, M., Ennico, K., Hermalyn, B., Marshall, W., Ricco, A., Elphic, R., Goldstein, D., Summy, D., Bart, G., Asphaug, E., Korycanski, D., Landis, D., Sollitt, L., *Science*, vol 330, p. 463-467

[4] Gladstone, G., Hurley, D., Retherford, K., Feldman, P., Pryor, W., Chaufray, J., Versteeg, M., Greathouse, T., Steffl, A., Troop, H., Parker, J., Kaufmann, D., Egan, A., Davis, M., Slater, D., Mukherjee, J., Miles, P., Hendrix, A., Colaprete, A., Stern, A., Science, vol 330, P. 472-476.

[5] Paige, D., et.al., 2010, Diviner Lunar Radiometer Observations of Cold Traps in the Moon's South Polar Region, Science, vol 330, p. 479-482.

[6] Chart by Richard Elphic using data generated by the LOLA instrument team.